

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.: 09/921,323 Confirmation No.: 5051
Applicant(s): Gillespie et al.
Filed: August 2, 2001
Art Unit: 1794
Examiner: J. A. Steele
Title: SPUNBOND NONWOVEN FABRICS FROM RECLAIMED POLYMER
AND THE MANUFACTURE THEREOF

Docket No.: 034423/237429
Customer No.: 00826

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

APPEAL BRIEF UNDER 37 CFR § 41.37

This Appeal Brief is filed pursuant to the "Notice of Appeal to the Board of Patent Appeals and Interferences" filed December 18, 2007.

1. ***Real Party in Interest.***

The real party in interest in this appeal is Fiberweb Simpsonville, Inc., the assignee of the above-referenced patent application.

2. ***Related Appeals and Interferences.***

There are no related appeals and/or interferences involving this application or its subject matter.

3. ***Status of Claims.***

Claims 1, 4 – 10, 20 and 29 – 30, which are all of the claims in this application, are under Final Rejection.

4. ***Status of Amendments.***

As indicated in the Advisory Action dated November 5, 2007, the Amendment filed on October 23, 2007 has been entered and is considered to overcome the 35 USC 112 rejection. The Terminal Disclaimer is considered to overcome the Double Patenting Rejection.

5. ***Summary of Claimed Subject Matter.***

As defined in independent claim 1, the invention is directed to a process for producing spunbond nonwoven fabric (indicated at 40 in the drawing figure). As stated at page 2 line 28 to page 3 line 16 of the specification the process comprises the following steps:

Step	Explanation
separately melting two or more polypropylene polymer components, at least one component including reclaimed polypropylene recovered from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;	Extruders 11 and 12 are used for separately melting the polymer components. The polymer material is typically provided in granular or flake form and fed to the extruders by supply hoppers 13, 14. Reclaimed polypropylene is fed to one hopper. Alternatively, as described at page 5 line 23 to page 6 line 2, an auxiliary feed extruder (not shown) can be used for melting polypropylene webs or filaments in order to supply molten reclaimed polypropylene to the extruder 12.
separately directing the two or more molten polypropylene polymer components through a distribution plate configured so that the separate molten polymer components combine at a multiplicity of spinnerette orifices to form bicomponent filaments containing the two or more polymer components, the polymer components being arranged in a sheath-core cross-sectional configuration, with the polymer component containing reclaimed polypropylene being present in the core, and the reclaimed polypropylene being in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the	See page 6, lines 3 to page 7 line 5. A spin beam assembly 20 receives molten polymer from each extruder 11, 12. Mounted to the spin beam assembly is one or more replaceable spin packs. At the downstream end or bottom of each spin pack is a spinnerette plate 22 having capillary orifices through which the molten polymer is extruded in the form of filaments. A distribution plate 24 located above the spinnerette plate forms channels for separately conveying the molten polymer streams so that the streams combine at each orifice in a sheath-core configuration, with the reclaimed polypropylene present in the core in

filaments being 25% by weight or greater	the specified amount.
extruding the multicomponent filaments from the spinnerette orifices into a quench chamber;	The quench chamber is indicated at 30. See page 7 lines 18 to 28.
directing quench air from a first independently controllable blower into the quench chamber and into contact with the filaments to cool and solidify the filaments;	Blower 31 directs quench air into the quench chamber 30.
directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;	The filament attenuator is indicated at 32. As the filaments and the quench air move downwardly, the cross sectional configuration of the attenuator 32 causes the quench air to be accelerated, and the entrained filaments are attenuated and stretched.
directing the filaments from the attenuator into and through a filament depositing unit;	The filament depositing unit 34 randomly distributes the filaments.
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments;	The randomly distributed filaments are deposited onto a moving belt 40. Page 7 line 29 to page 8 line 8.
applying suction from a second independently controllable blower beneath the air-permeable belt so as to draw air through the depositing unit and through the air-permeable belt; and	A suction unit 42 beneath the belt 40 assists in the lay-down of the filaments on the belt. Page 8 lines 1 to 8.
directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.	A bonder, shown in the drawing in the form of a pair of heated calender rolls, bonds the filaments to form a coherent nonwoven fabric. Page 8 lines 14 to 20.

Independent claim 7 recites a similar sequence of method steps, but is more specific in that the first polymer component is defined as comprising virgin polypropylene and the second

polymer component comprises reclaimed polypropylene, and wherein the first component forms the sheath and the second component forms the core.

Independent claim 10 begins with the step of reclaiming polypropylene from previously spun polypropylene fiber or webs comprises of previously spun polypropylene fiber, followed by separately melting a first polymer component comprising virgin polypropylene and a second polymer component comprising the reclaimed polypropylene. The subsequent steps are similar to claim 7.

Independent claim 29 recites a series of steps similar to claim 7, but is more specific in defining how the first and second molten polymer components are directed through a series of plates of the spin pack and distribution plate.

Independent claim 30 also recites a series of steps similar to claim 7, but is more specific in defining the spin back and spinnerette orifice density, and that the distribution plate is a thin etched distribution plate.

6. ***Grounds of Rejection to be Reviewed on Appeal.***

Claims 1 – 10, 29 and 30 stand rejected under 35 U.S.C. 103(a) as being obvious over Hills US 5,162,074 in view of Geus et al. US 5,814,349 and further in view of Mleziva et al. US 6,410,138 and Handbook of Fiber Chemistry, 3rd edition. This is the sole ground of rejection on appeal.

According to the rejection, it would have been obvious to add the attenuation process and air permeable belt process of Geus et al. to the process of Hills, and it would have been obvious to use reclaim polypropylene as described by Mleviza et al. The rejection further asserts that it would have also been obvious to use the combination of reclaim polypropylene and virgin polypropylene.

7. ***Argument.***

To establish a *prima facie* case of obviousness, three basic criteria must be met: 1) the prior art reference (or references when combined) must teach or suggest all the claim elements; 2) there must be some motivation to combine the references; and 3) there must be a reasonable expectation of success.

The Examiner has failed to make a prima facie case of obviousness 1) because the combination of references fails to teach each and every claim element and 2) because there is no motivation to combine the references. Further, the references cannot be combined in a predictable way to arrive at the claimed invention.

A. The references do not teach or suggest all of the claim elements

The combination of Hills, Geus et al. and Mleziva as set forth in the rejection does not result the process defined by Applicants in the claims of record. In particular, Mleziva, considered singly or in any combination with Hills and/or Geus et al. does not teach a process in which polypropylene is used in both components of sheath-core bicomponent filaments and wherein reclaimed polypropylene is located in the core of the sheath core bicomponent filament and is provided in the core at up to 100% by weight, with the total amount of reclaimed polypropylene in the filaments being at a level of 25% by weight or greater.

Mleziva is directed to the manufacture of crimped multicomponent filaments and to a spunbond web made from these filaments. The multicomponent filaments are made from two different polymer components A and B. According to the Mleziva teachings at column 7, lines 2-4, "Polymer component A and polymer component B must be selected so that the resulting bicomponent filament is capable of developing a natural helical crimp." Preferably, polymer component A has a faster solidification rate, and in one embodiment it has a higher melting temperature than polymer component B. In particular, Mleziva uses polypropylene as polymer component A and polymer component B is polyethylene or a random copolymer of propylene and ethylene. Mleziva also teaches incorporating a crimp enhancement additive, such as a butylene-propylene random copolymer, into polymer component B.

Applying the Mleziva teachings to the modified Hills/Geus spunbond process would require having the two components of the bicomponent filaments formed from two different polymer compositions, e.g. polypropylene in one component and polyethylene or an ethylene copolymer in the other component. The Mleziva teachings would not lead to the combination claimed by applicant in claim 1, where both the sheath and core components are polypropylene, or to the combination more specifically defined in independent claims 7, 10, 29 and 30, where the sheath component comprises virgin polypropylene and the core component comprises reclaimed polypropylene.

Applicants are unable to follow or to accept the Examiner's explanation in the September 18, 2007 rejection attempting to justify why this difference between the claimed invention and Mleziva's teachings can be ignored.

In the only disclosure of a sheath-core bicomponent filament (FIG. 2B and the accompanying text), the Mleziva reference describes an eccentric sheath core filament containing a core component A which is preferably polypropylene and a sheath component B which is preferably polyethylene and contains the crimp enhancing additive. At column 8, lines 6 to 22, Mleziva et al. mention that reclaimed and recycled polymers can be used. However, Mleziva et al. clearly teach that the reclaimed polymer is added to the polymer component B that forms the sheath component. Specifically, the patent states that the reclaimed polymer can be added to this component in an amount up to about 20 percent by weight.

Applicants' invention as defined in the claims of record thus differs over the Mleziva reference in a number of significant and fundamental respects.

- The claims require the use of polypropylene in both the sheath and core component. Mleziva has polypropylene in one component and polyethylene or a copolymer of propylene and ethylene in the other component.
- Each of the independent claims of record clearly specifies a process in which the polymer component containing reclaimed polypropylene is present in the core of the sheath core bicomponent filament. In the Mleziva reference, the reclaim polymer is present in the sheath.
- Each of the independent claims also specifies that the reclaim polymer comprises at least 25 percent by weight of the filament. This is outside of the teachings of Mleziva. The reference contains a clear and explicit teaching that reclaim can be added "in an amount up to about 20% by weight." Applicant submits that the person of ordinary skill in the art would have no reason to ignore this clear and explicit teaching by Mleziva.

In addition to the foregoing reasons, Applicants submit that there are additional and independent reasons why certain other claims are patentable over the prior art. Claims 4 and 9 specify that the polymer component forming the core is formed entirely of reclaimed polypropylene. This is not taught by Mleziva or by any of the other cited prior art documents. Claims 7, 10, 29 and 30 specify that the sheath contains virgin polypropylene and the core comprises reclaimed polypropylene. The only teaching of using reclaimed polypropylene comes

from Mleziva. However, Mleziva never teaches the combination of virgin polypropylene in the sheath and reclaimed polypropylene in the core.

For the foregoing reasons, the fundamental prerequisite of a *prima facie* obviousness rejection, i.e. that the prior art references must teach or suggest all the claim elements, has not been met. Therefore the rejection can not be sustained.

B. *There is no motivation to combine the references*

Applicant has discovered that by following a prescribed series of process steps, as defined in the claims of record, it is possible to produce a spunbond nonwoven fabric at the high speeds which are necessary for practical and economical commercial production, and wherein the nonwoven fabric contains reclaimed polypropylene at high levels not previously attainable¹. In particular, as defined in the claims, the reclaimed polypropylene is present in the core in an amount up to 100% by weight, and the total amount of reclaimed polypropylene in the filaments is 25% or higher. It is not obvious or evident that reclaimed polypropylene can be successfully incorporated into a spunbond process at this high level, and it is not obvious how to achieve the incorporation of such a high level of reclaim in a spunbond process.

The prior art relied upon in the rejection provides no insight or direction to the person of ordinary skill on how to achieve these objectives. The Hills patent and the Geus et al. patent do not even address the issue of how to incorporate reclaimed polypropylene into a spunbond nonwoven fabric, and so it is evident that they do not and can not point the way to a solution.

Instead, the rejection arrives at the Applicants' claimed invention by cobbling together process steps taken from otherwise unrelated synthetic fiber manufacturing processes: a spin pack assembly as described in the Hills patent; a filament attenuator and filaments lay-down system as described by Geus et al. and a crimped multicomponent filament process described by

¹ The Background portion of Applicant's specification, pages 1 and 2, notes that the nonwovens industry has previously attempted to use recycled polypropylene in nonwoven fabrics, but the recycled polypropylene is blended with virgin polypropylene, and the amount of recycled polypropylene that can be used has been limited to less than about 20% of the total polypropylene weight. Using too much recycled polypropylene causes a reduction in strength and quality defects in the nonwoven fabric or, in severe cases, a complete disruption of the manufacturing process.

Mleziva et al. Clearly lacking from this rejection, however, is any rational basis why one of ordinary skill in the art would (1) select only these spunbond process steps from among the many available processes known in the industry, (2) and then assemble these process steps in the particular manner as set forth in the rejection so as to arrive at the specific and lengthy sequence of process steps as recited in the claims of record. Also, since it was previously known that recycled polypropylene can only be used successfully in a spunbond process in limited amounts, the person of ordinary skill in the art had no way of predicting that high levels of recycled polypropylene (25% by weight or greater and up to 100% in the core as claimed) could be successfully incorporated into a spunbond nonwoven fabric by this process. There is no reasonable expectation of success.

In determining whether it is obvious to have selected the process steps taken from Hills, Geus et al. and Mleziva et al. as set forth in the rejection, it is relevant to consider the number of choices available to the person of ordinary skill in the art. There are many different kinds of spunbond processes known to persons of ordinary skill in the art. To illustrate this point, applicant submitted in the response filed on July 10, 2007 pages from a Nonwovens Training Course given by the EDANA, the European Disposables and Nonwovens Association and by INDA, the Association of the Nonwoven Fabrics Industry. This document is provided in the Evidence Appendix. This text shows that there are a variety of web forming technologies that can be used to produce a spunbond nonwoven fabric. The text explains that the spunbond process starts with an extruder feeding molten polymer to a spinneret which converts the polymer into a series of molten polymer filaments, and that “from this point onwards ***there are a whole range of alternative systems.***” (emphasis added) The text explains a number of variations in how the filaments can be drawn and distributed on a collector belt. For example, the filaments can be drawn either mechanically by draw rolls or pneumatically. A number of alternative airflow systems have been developed for pneumatically drawing and attenuating the filaments as illustrated in Fig. 5.4. Examples of different commercially available spunbond systems include the Freudenberg “Lutravil” process, DuPont’s development of the Reemay and Typar spunbond processes, and the “Docan process” made available by Lurgi Kohle and Mineralotechnick GmbH. Indeed, there are even variations and modifications of the basic Lurgi-Docan process. Other spunbond technologies include the Corovin “Multidenier” and Fiberweb “S-Tex” technologies, the Zimmer NST system illustrated in Figures 5.12, 5.13, 5.14 and 5.15, several

variants of the Reifenhauser "Reicofil" spunbond system, spunbond systems from Kobe Steel and from Nippon Kodoshi Corporation as illustrated in Figures 5.18 and 5.19 and the Ason Engineering Inc. spunbond system. From Table 5.2 it will be seen that there are many process variables that must be controlled in a spunbond system. From this evidence, it should be apparent that the person of ordinary skill in the art is faced with a myriad of choices from the available spunbond technologies.

Why, therefore, would the person of ordinary skill in the art have a reason to pick the spunbond system of Geus et al. rather than one of the many other available choices as illustrated above? In the absence of some guidance or direction, a person of ordinary skill in the art would have no reason to favor the Geus et al. system over the other available choices.

Having selected the Geus et al. system, why would the person of ordinary skill in the art take only selected process steps of the Geus et al. system and discard the remainder of the Geus et al. system? In the absence of some guidance or direction, a person of ordinary skill in the art would not be motivated to take individual isolated process steps from the Geus et al. system, apply these to the process of Hills, and discard the remainder of the Geus et al. system.

The rejection asserts that it "would have been obvious to add the attenuation process and air permeable belt process of Geus to the process of Hills motivated to improve the productivity of the spun bond manufacturing process." If improved productivity is the motivation, there is nothing in the reference itself that would lead the person of ordinary skill to conclude that the Geus process provides productivity superior to the other available choices, nor is there anything leading the skilled person to select only the Geus attenuation process and air permeable belt process from the overall Geus system. Also, the person of skill in the art has no way of predicting whether the attenuation process and air permeable belt process of Geus are capable of operating independently when taken out of the complete system contemplated by Geus et al. or, if operable independently, that they would provide improved productivity in another context altogether when joined to the Hills spin pack assembly. The person of skill in the art had no way of predicting whether these components could be combined to produce a workable system.

Introducing Mleziva into the rejection makes the newly reconstructed system arrived at by combining the references even more complicated, and this further underscores the impropriety of the rejection. The logic asserted as the motivation for justifying the combination of Hills and Geus et al. is tenuous, at best, for the reasons just given. The logic collapses when

Mleziva is added to the mix. It is asserted that it would have been obvious to use reclaim polypropylene, motivated by a desire to use polymer scrap and waste as described by Mleziva. However, the Examiner ignores the fact that Mleziva's actual teachings regarding the use of reclaim polymer are in a very specific context. The rationale used in the rejection ignores this specific context and then twists the actual teachings to arrive at a conclusion not even contemplated by Mleziva.

Mleziva teaches that reclaimed and recycled polymers can be added to the polymer component B, which is used in the sheath component of bicomponent filaments. See column 8 lines 6 to 8. Mleziva teaches that the crimp enhancement additive present in polymer component B functions as a compatibilizer that facilitates mixing between the polyethylene and a reclaimed polymer that contains a mixture of polyethylene and polypropylene. If this teaching is given credence, it may possibly lead someone to attempt to incorporate reclaimed polymer into the sheath of a bicomponent filament which also has a crimp enhancement additive. But there is no basis for concluding that this teaching provides a motivation to arrive at the invention claimed by applicant, where the recycle is located in the core component, not the sheath. The reasons why Mleziva can use reclaim polymer in the sheath do not apply to the core, which does not contain the crimp enhancement additive.

Mleziva teaches further that the reclaim polymer can be added up to about 20% by weight. This is consistent with what is stated in the background portion Applicants' specification as noted in the earlier footnote. This teaching would not provide motivation to incorporate recycle into the core component of a bicomponent filament at levels much higher than ever used before, i.e. greater than 25% by weight as claimed and up to 100% in the core.

In determining obviousness, the Supreme Court in *KSR International Co. v. Teleflex Inc.*, 127 S. Ct. 1727, 1739 (U.S. 2007), held that one must look to whether the combination of the elements provides a predictable result. In the present case, one of ordinary skill in the art would not be motivated to combine the processes of Hill, Geus and Mleziva because their disparate teachings cannot be combined in a predictable way to arrive at the claimed invention.

Persons familiar with the manufacture of spunbond nonwoven fabrics know that the spunbond process is complex and that the various process components of a spunbond process are interdependent. Making even minor changes in the process can result in off-quality product or filament breakages that can result the entire disruption of the manufacturing line. The

modifications resulting from the combination of the Hills, Geus and Mleziva references amounts to an entirely new and redesigned system which is a different process from anything previously used. The skilled worker would be unable to predict whether this redesigned process would operate reliably or at all. Incorporating reclaim polypropylene into a spunbond nonwoven fabric at the high levels set forth in the claims had never been achieved before, and it is entirely unforeseeable and unpredictable whether the combination of process steps as set forth in the claims would be operable.

For the reasons noted, the motivation required for substantiating a *prime facie* obviousness rejection is lacking. The rejection should therefore be reversed.

8. ***Claims Appendix.***

A claims appendix containing a copy of the claims on appeal is attached at pages 13 to 17 of this brief.

9. ***Evidence Appendix.***

A copy of the document submitted with the Response filed on July 10, 2007 is enclosed following the claims appendix.

10. ***Related Proceedings Appendix***

None

CONCLUSION

In view of the foregoing arguments, it is submitted that the invention defined by the claims of record is patentable over the cited prior art. A decision from the Board of Patent Appeals and Interferences reversing the final rejection is solicited.

Respectfully submitted,



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CLAIMS APPENDIX

1. A process for producing spunbond nonwoven fabric, comprising the steps of:
separately melting two or more polypropylene polymer components, at least one component including reclaimed polypropylene recovered from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;
separately directing the two or more molten polypropylene polymer components through a distribution plate configured so that the separate molten polymer components combine at a multiplicity of spinnerette orifices to form bicomponent filaments containing the two or more polymer components, the polymer components being arranged in a sheath-core cross-sectional configuration, with the polymer component containing reclaimed polypropylene being present in the core, and the reclaimed polypropylene being in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the filaments being 25% by weight or greater;
extruding the multicomponent filaments from the spinnerette orifices into a quench chamber;
directing quench air from a first independently controllable blower into the quench chamber and into contact with the filaments to cool and solidify the filaments;
directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;
directing the filaments from the attenuator into and through a filament depositing unit;
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments;
applying suction from a second independently controllable blower beneath the air-permeable belt so as to draw air through the depositing unit and through the air-permeable belt;
and
directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.
4. The process according to Claim 1, wherein the polymer component forming the core is formed entirely of said reclaimed polypropylene.

5. The process according to Claim 4, wherein the sheath is formed entirely of virgin polypropylene.

6. The process according to Claim 4, wherein the sheath is formed of a blend of virgin polypropylene and reclaimed polypropylene recovered from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber.

7. A process for producing a spunbond nonwoven fabric, comprising the steps of:
separately melting a first polymer component comprising virgin polypropylene and a second polymer component comprising reclaimed polypropylene recovered from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;

separately directing the first and second molten polymer components through a distribution plate configured so that the separate molten polymer components combine at a multiplicity of spinnerette orifices to form bicomponent filaments containing a core of the second polymer component and a surrounding sheath of the first polymer component, with the core containing reclaimed polypropylene in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the filaments being 25% or greater;

extruding the bicomponent filaments from the spinnerette orifices into a quench chamber;
directing quench air from a first independently controllable blower into the quench chamber and into contact with the filaments to cool and solidify the filaments;

directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;

directing the filaments from the attenuator into and through a filament depositing unit;
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments;

applying suction from a second independently controllable blower beneath the air-permeable belt so as to draw air through the depositing unit and through the air-permeable belt;
and

directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.

8. A process according to Claim 7, wherein the second polymer component has a melt flow rate at least 5 units greater than that of the first polymer component.

9. A process according to Claim 7, wherein the core is formed entirely of said reclaimed polypropylene.

10. A process for producing a spunbond nonwoven fabric, comprising the steps of:
reclaiming polypropylene from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;

separately melting a first polymer component comprising virgin polypropylene and a second polymer component comprising the reclaimed polypropylene;

separately directing the first and second molten polymer components through a distribution system configured so that the separate molten polymer components combine at a multiplicity of spinnerette orifices to form bicomponent filaments containing a core of the second polymer component and a surrounding sheath of the first polymer component, with the core containing reclaimed polypropylene in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the filaments being 25% by weight or greater;

extruding the bicomponent filaments from the spinnerette orifices into a quench chamber;
directing quench air into the quench chamber and into contact with the filaments to cool and solidify the filaments;

directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;

directing the filaments from the attenuator into and through a filament depositing unit;
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments; and

directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.

29. A process for producing spunbond nonwoven fabric, comprising the steps of:
separately melting a first polymer component comprising virgin polypropylene and a second polymer component comprising reclaimed polypropylene recovered from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;

separately directing the first and second molten polymer components to a spin beam assembly equipped with spin packs assembled from a series of plates sandwiched together, including a top plate having inlet ports for receiving the first and second molten polymer components, a metering plate having flow distribution apertures formed therein arranged for distributing the separate first and second molten polymer components, a spinnerette plate having a multiplicity of spinnerette orifices, and upstream from the spinnerette plate, a distribution plate which forms channels configured so that the separate molten polymer components combine at said spinnerette orifices to form bicomponent filaments containing the first and second polymer components, the polymer components being arranged in a sheath-core cross-sectional configuration, with the polymer component containing reclaimed polypropylene being present in the core, and the reclaimed polypropylene being in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the filaments being 25% by weight or greater;

extruding the multicomponent filaments from the spinnerette orifices into a quench chamber;

directing quench air from a first independently controllable blower into the quench chamber and into contact with the filaments to cool and solidify the filaments;

directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;

directing the filaments from the attenuator into and through a filament depositing unit;
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments;

applying suction from a second independently controllable blower beneath the air-permeable belt so as to draw air through the depositing unit and through the air-permeable belt;
and

directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.

30. A process for producing a spunbond nonwoven fabric, comprising the steps of:
reclaiming polypropylene from previously spun polypropylene fiber or webs comprised of previously spun polypropylene fiber;

separately melting a first polymer component comprising virgin polypropylene and a second polymer component comprising the reclaimed polypropylene;

separately directing the first and second molten polymer components to a spin beam assembly equipped with spin packs assembled from a series of plates sandwiched together including a spinnerette plate having a multiplicity of spinnerette orifices having a density of at least 3000 orifices per meter of length of the spin beam, and upstream from the spinnerette plate, a thin etched distribution plate which forms channels configured so that the separate molten polymer components combine at said spinnerette orifices to form bicomponent filaments containing a core of the second polymer component and a surrounding sheath of the first polymer component, with the core containing reclaimed polypropylene in an amount up to 100% by weight, and with the total amount of reclaimed polypropylene in the filaments being 25% by weight or greater;

extruding the bicomponent filaments from the spinnerette orifices into a quench chamber;
directing quench air into the quench chamber and into contact with the filaments to cool and solidify the filaments;

directing the filaments and the quench air into and through a filament attenuator and pneumatically attenuating and stretching the filaments;

directing the filaments from the attenuator into and through a filament depositing unit;
depositing the filaments from the depositing unit randomly upon a moving continuous air-permeable belt to form a nonwoven web of substantially continuous filaments; and

directing the web through a bonder and bonding the filaments to convert the web into a coherent nonwoven fabric.

Evidence Appendix.

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COURSE NOTES**

September 1998

Pages from this course are attached following this page.

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DISCLAIMER

The material presented in the text of the various Modules that make up this Nonwovens Training Programme and the verbal and visual presentations that accompany them are given in good faith but without guarantee.

Whilst every effort has been made to check the information presented, no claim is made for the completeness of any advice given, nor for the legal aspects and obligations of employers and employees in relation to the legislative and regulatory aspects of some material.

EDANA September 1998.

Web Forming technologies - Wetlaid Nonwovens
- Short fibre airlaid Nonwovens

Short fibre airlay technology	
Introduction and background	4.21
Process technology M &J Fibertec	4.23
- DanWeb	4.25
- Honshu	4.28
Absorbent product applications	4.28
Recent developments - commercial	4.29
- technical	4.29
- superabsorbent	4.30
- markets	4.31

Polymer to Web Nonwovens	
Spunlaid nonwovens	5.1
Melt spinning	5.3
Process Options	5.4
Air flow systems	5.5
DuPont Technology	5.8
System developments	5.9
Lurgi 'Docan'	5.10
Reinfehauser 'Reicofil'	5.11
Spunbond process variables	5.13
Recent developments	5.13
Developments by companies	5.13
Developments of existing systems	5.14
-Zimmer	5.15
- Reifenhauer	5.19

New developments - Kobe Steel	5.20
- Nippon Kodoshi	5.21
- ASON Engineering	5.22

Melt Blown Nonwovens	5.26
Raw materials	5.27
Web properties	5.28
Process schematics	5.31
Summary	5.34
Process parameters	5.34
Meltblown webs for filtration	5.36
Electrostatic spinning	5.37
Foam spinning	5.41
Fibrillated film	5.42
Melt spun films	5.45
Connulated 'formed' films	5.45
Other related nonwoven processes	5.48

MODULE 6

Web Bonding Technologies - Chemical Bonding

Introduction	6.1
Latex binders	6.2
Emulsion polymerisation	6.4
Polymerisation initiation	6.6
Monomers -ethylene	6.7
-styrene	6.8
-vinyl acetate	6.9
- acrylics	6.9
- butadiene	6.11
Post compounding	6.12
Binder performance	6.12
cohesion	6.13
adhesion	6.14
binder distribution	6.14
Binder utility	6.15
Latex binders - summation	6.16
Recent developments	6.16
Effect of latex binders on nonwoven	6.17
Effect of different fibre composition	6.18

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Module 5

Web Forming Technologies
Polymer to Web Nonwovens

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Module (5)**Polymer to Web Nonwovens - Spunlaid, Melt blown and film based.****SPUNLAID NONWOVENS****Introduction**

Whereas the staple fibre nonwoven process utilises suitable **fibres** to produce carded webs which are then mechanically bonded, calender bonded, or chemically bonded to produce a staple fibre nonwoven, the spunbond process starts with polymer chips of the selected polymer and by melting the polymer chips produces **continuous filaments** of polymer that are laid down to form the web.

Therefore the production of spunbond webs requires the simultaneous control of four integrated operations, namely:-

- a) filament extrusion (from the molten polymer)
- b) filament drawing (orientation of the polymer molecules)
- c) filament laydown (collation of the filaments to form a web)

These three functions are known as the spunlaid operation

- d) the web bonding stage

Web bonding can be any one or more of a number of processes which include needlepunch, chemical bonding, thermal bonding etc. and its main function is to consolidate the filaments into a usable web.

A typical outline process schematic is shown in **FIGURE 5.1**

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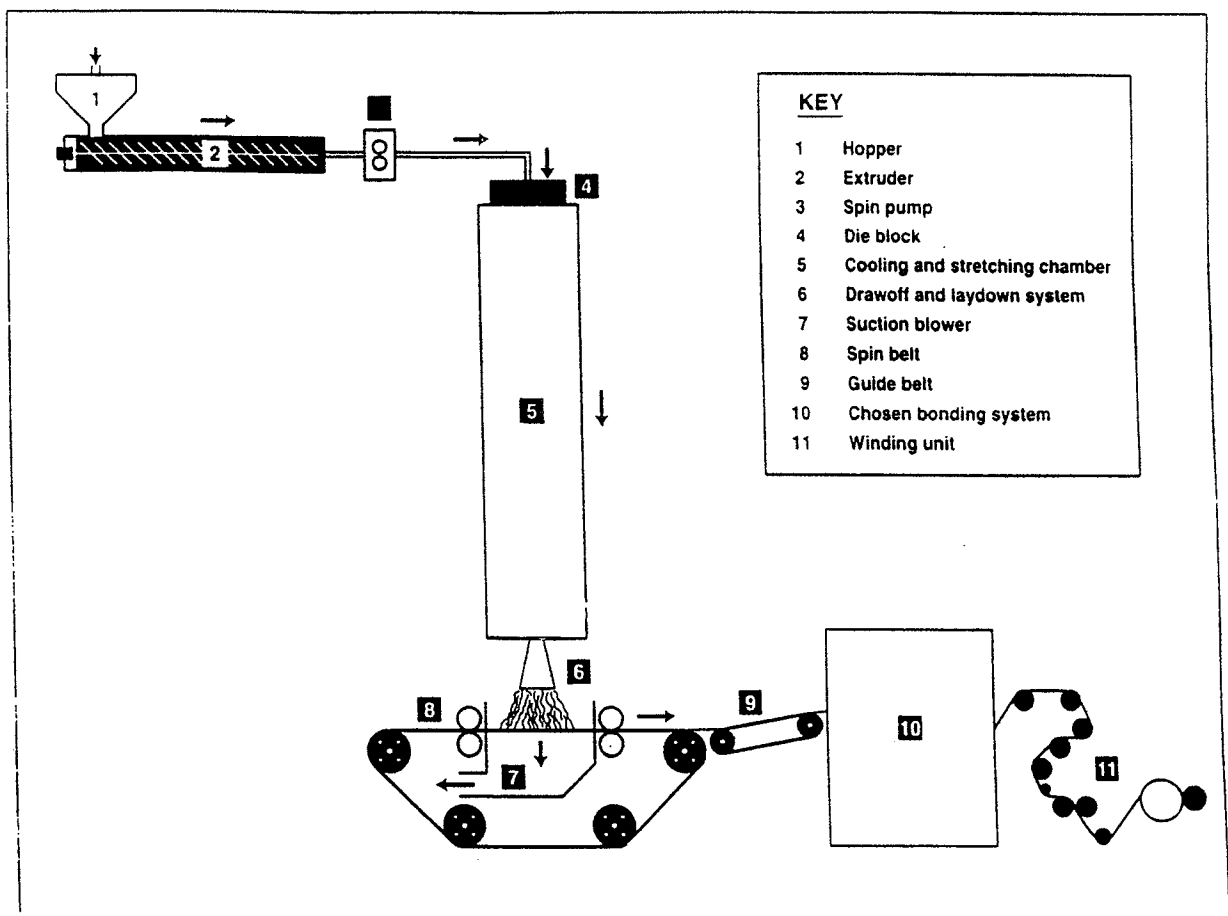


FIGURE 5.1 Process schematic of a typical spunbond process.

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The spinning part of the process is closely related to the melt spinning technology used to produce threads or staple fibres from meltable polymers.

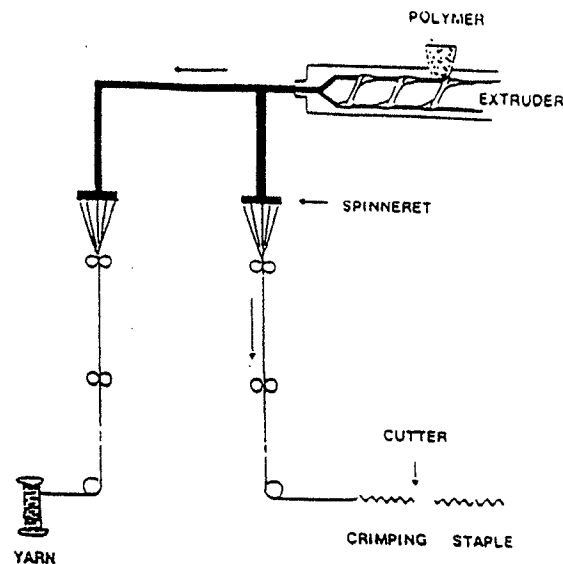


FIGURE 5.2 Melt spin process to produce yarns or staple fibres from thermoplastic polymers.

Figure 5.2 shows polymer being fed to an extruder. This polymer could be pellets of polypropylene, polyester, nylon or various other thermoplastic polymers.

Hot polymer flows from the extruder and as it exits it is forced through spinnerets to produce filaments of polymer. These spinnerets have small holes that can be of many different shapes and sizes which results in the filaments produced also being of many different shapes and sizes if so required.

Filaments so produced are normally drawn (stretched) to produce a filament with the required characteristics and this can be either wound up as a continuous thread or cut into staple length fibres.

The spunbond process starts with the basic extruder feeding molten polymer through a pumping system to a spinneret which converts the polymer feed into a series of molten polymer filaments.

From this point onwards there are a whole range of alternative systems.

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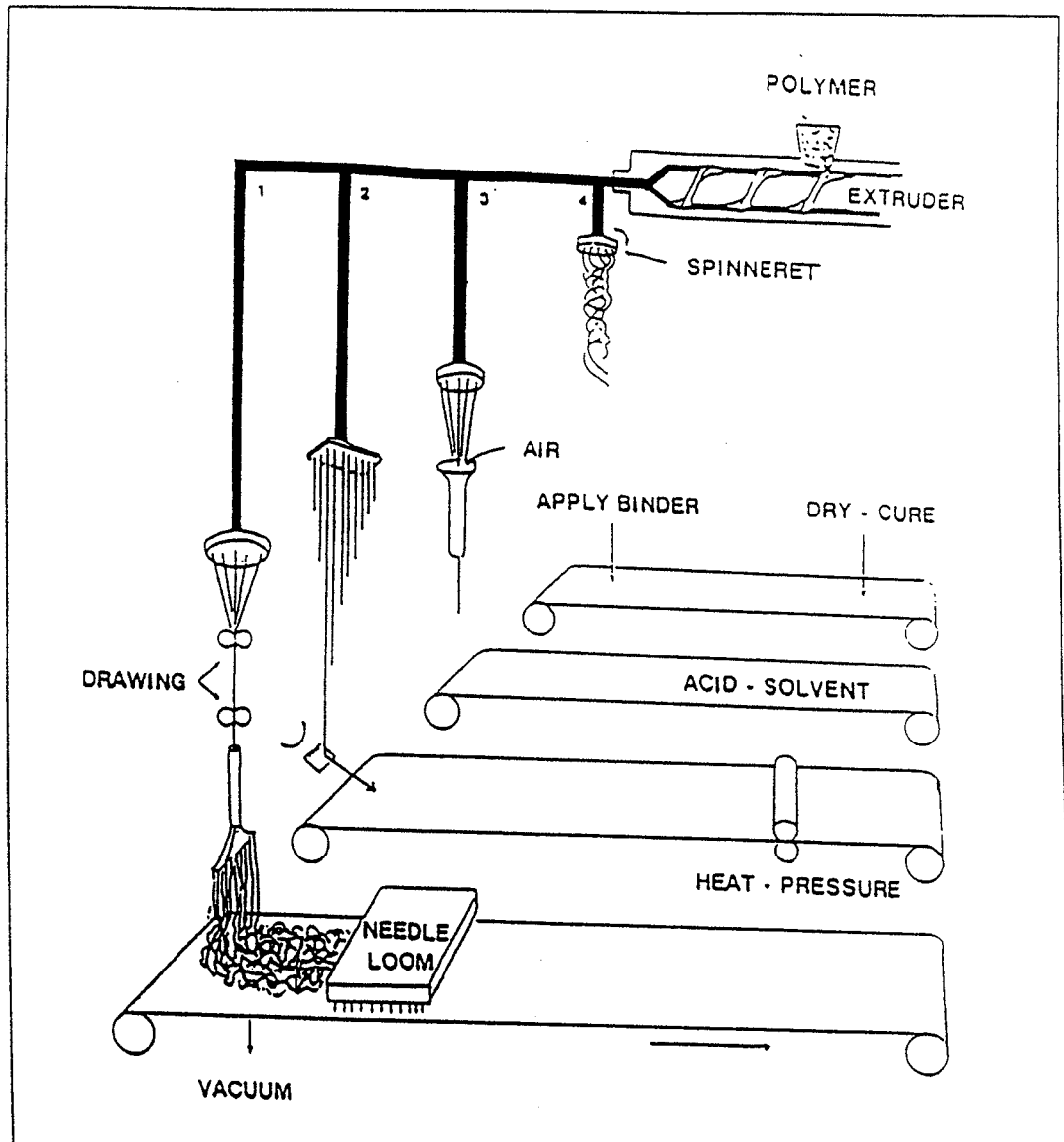


FIGURE 5.3 Spinning and web bonding options to produce spunbonded nonwovens.

In 5.31 filaments are mechanically drawn and distributed on a collector belt which passes through a needle loom. The barbed needles entangle the filaments yielding a web with integrity. By adjusting the speed of the collector belt heavy weight fabrics can be made.

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In 5.32 filaments are air drawn and spread on the collector belt. The filaments are bonded together as they pass between two heated rolls.

In 5.33 an electric charge is applied to the filaments to assist dispersion. Bonding of the filaments could utilise an acid, solvent or gas to encourage the filaments to cohere and adhere to themselves at cross over points.

Figure 5.34 illustrates the use of a rotating spinneret for a unique filament dispersion system combined with the use of a binder addition (i.e. latex) followed by drying and curing.

The spinlaying and bonding processes provide an extremely versatile method for producing nonwoven webs.

Webs can be heat or sonic bonded, moulded, embossed, flocked or coated with relative ease, which means that in finishing the base webs can be readily converted to suit specific end use applications.

Airflow System Development

The major developments in the early stages of spunlaid nonwovens technology centred round the way in which air streams were used.

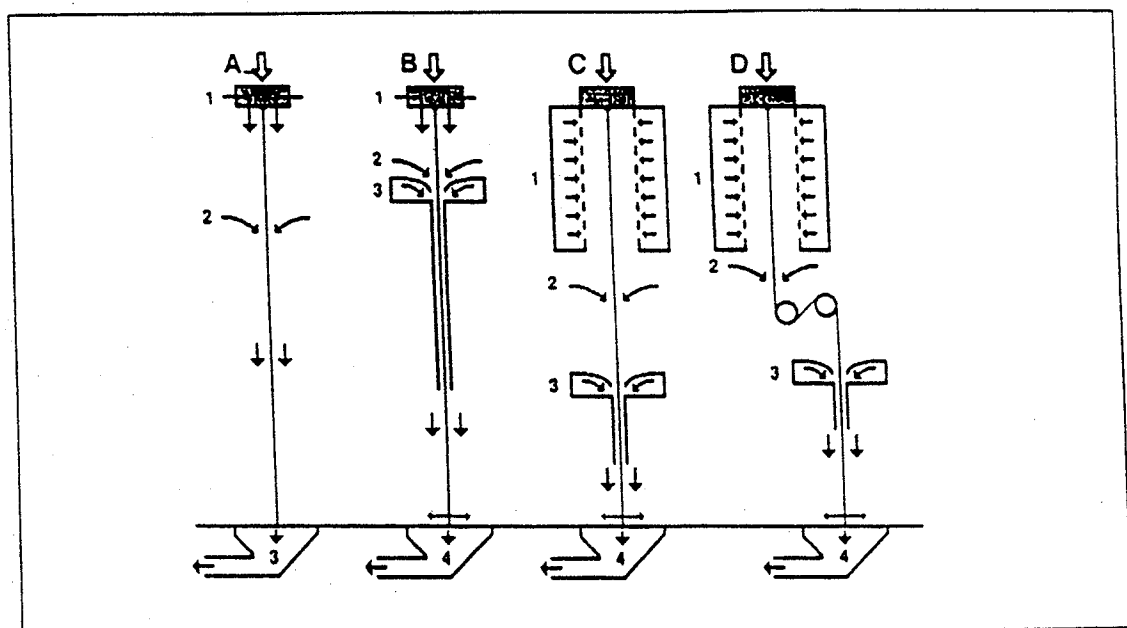


FIGURE 5.4 Alternative Airflow Systems

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Figure 5.4 Diagram A

Uses longitudinal spinnerets with air slots on both sides of the spinneret for the expulsion of drawing gas (1). The room air is (2) carried along and after laydown of the filaments, the air is removed by suction (3).

This process is well suited for 'tacky' polymers such as linear polyurethane. The web is truly laid and bonded in one step in that the continuous filaments after collection bond themselves at their cross over points due to their tackiness. Crystallisation then sets in and eliminates any further tackiness.

Figure 5.4 Diagram B

This arrangement allows a higher draw ratio, with subsequently increased molecular orientation of filaments.

Filaments are drawn with several air or gas streams (1) (2) and (3) using drawing conduits. The air is removed by suction after web formation.

This process has special advantages in preparing fine spunlaid webs with textile like appearance and 'hand' to the web.

Figure 5.4 Diagram C

Operates with regular cooling ducts (1) and drawing jets (3). The drawing and cooling arrangements can be operated to give very high spinning speeds with the result that highly oriented filaments are produced.

The room air (2) with a controlled temperature and moisture content, can be entrained to control fibre properties. The air is removed by suction (4) after web laydown.

Figure 5.4 Diagram D

This system has a mechanical drawing step (2) between the spinneret and the laydown zone. This system is similar to that used for conventional spinning and is especially useful for polymers where regular air drawing would not produce optimum filament molecular orientation.

In this system air streams are used for cooling (1) and laydown (3) with air removal by suction (4). Webs with high strength and low elongation can be made with this process.

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A large number of spinlay processes utilise one or other of these systems with varying degrees of modification.

Early Developments

The concept of the spunbond process was developed simultaneously in Europe and the United States in the late 1950's.

In Europe, Freudenberg filed several patents in 1959 and by 1965 their first spunbond process 'Lutrasil' based on polyamides was commercialised.

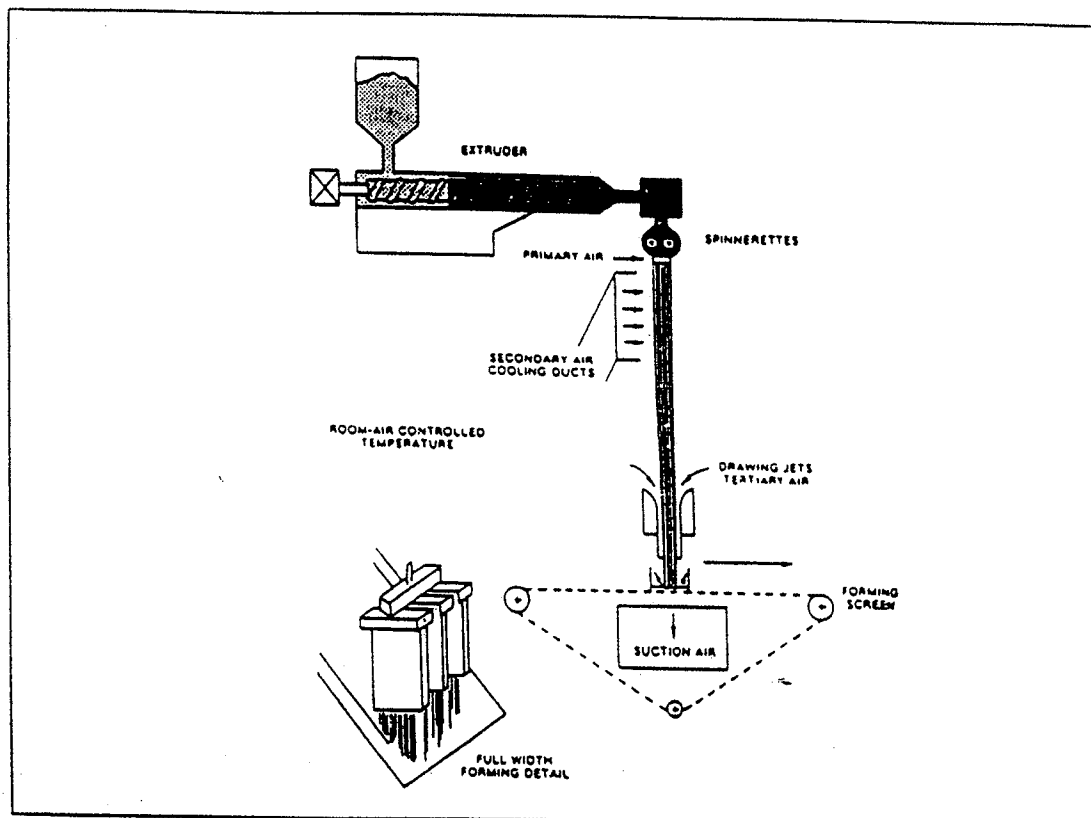


FIGURE 5.5 Schematic of Freudenberg 'Lutrasil' spinlay process.

This technology formed the basis of most of Freudenberg's early developments including the roofing substrate materials based on polyester.

In the USA, DuPont's research and development work resulted in 'Reemay' polyester products in 1965 and 'Tyvar' based on polypropylene two years later.

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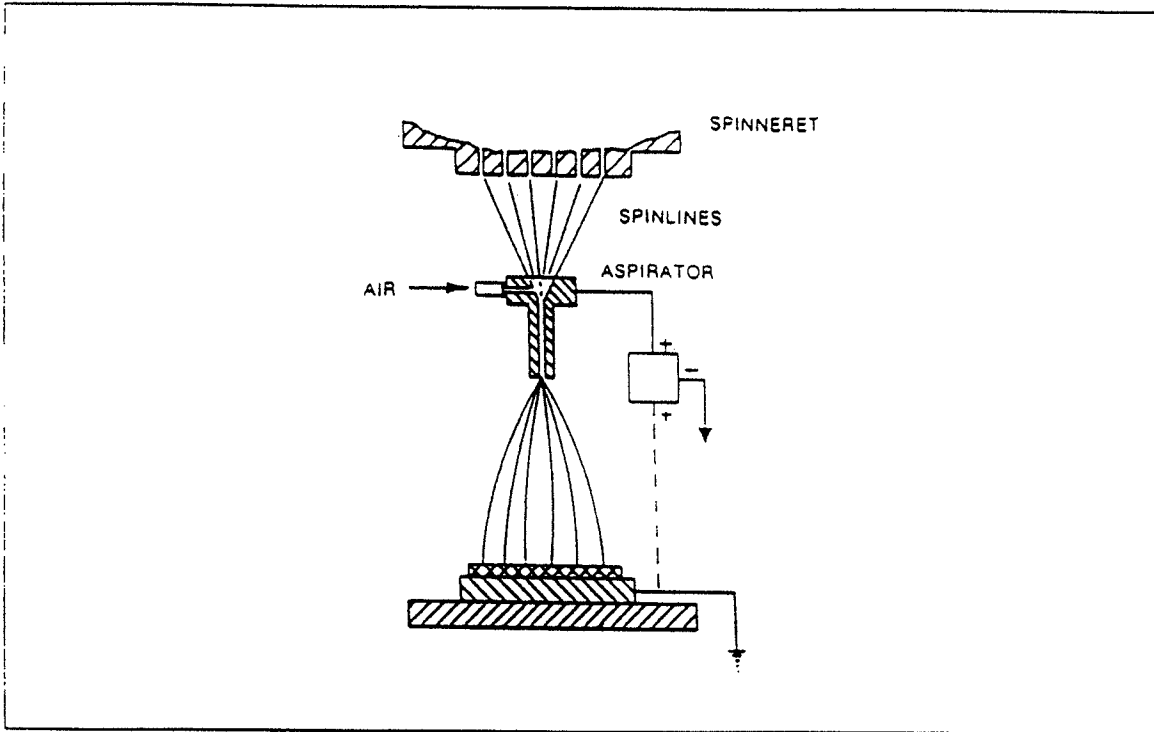


Figure 5.6 Schematic DuPont spinlaid technology.

DuPont initially developed 'Reemay', a spunbonded polyester which was followed by 'Typar' based on Polypropylene and 'Tyvek' where DuPont used the technique known as flash spinning to produce a web made up of many plexifilaments of high density polyethylene.

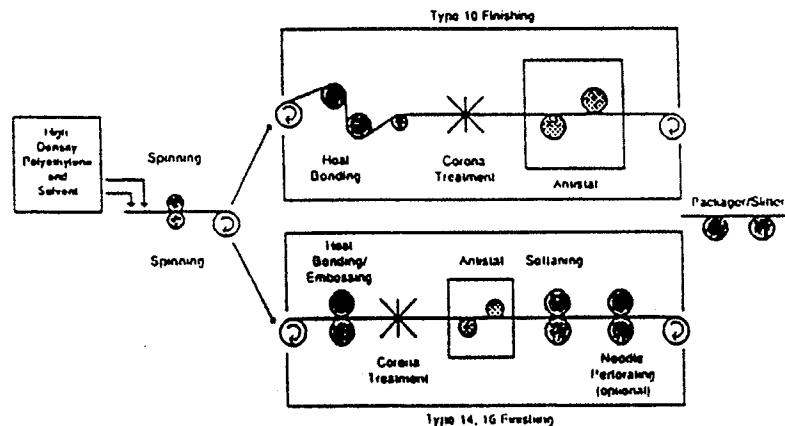


Figure 5.7 Schematic of flash-spun 'Tyvek' spunbonding system.

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The concept of flash spinning was to take a polymer such as high density polyethylene and at high temperature and pressure, 'dissolve' in the molten polymer a solvent (initially a chlorinated hydrocarbon now changed for environmental reasons) and then feed the molten polymer/solvent system to the spinneret.

At the spinneret the polymer/solvent system was depressurised and the solvent was removed from the molten polymer with almost explosive force, that is, it was 'flashed off' leaving a mass of plexifilaments of polyethylene which make up the web.

The 'Flash Spun' process is a unique and originally patented process which has been commercially very successful for DuPont, producing as it does nonwoven webs with unique properties, notably exceptional strength even with light weight webs. (see US Patent 3,860, 369)

System Developments

In 1970 Lurgi Kohle and Mineralotechnick GmbH introduced their 'Docan' process which was available for license. Licenses were taken up by a number of early entrants such as Kimberly-Clark and J H Beneke (now Corovin) in Germany and these early licenses extensively modified the original Lurgi-Docan technology.

The original 'Docan' systems were large capacity and difficult to control. Whilst the basic technology produced a web of filaments, and in the 1970's that was an achievement in itself, as the product became more accepted, so did the demands for better quality.

Early licensees, such as Kimberly-Clark and Beneke spent considerable research time and money and from the basic 'Docan' system developed their own proprietary additions and modifications which enabled them to produce the light weight materials for coverstock etc.

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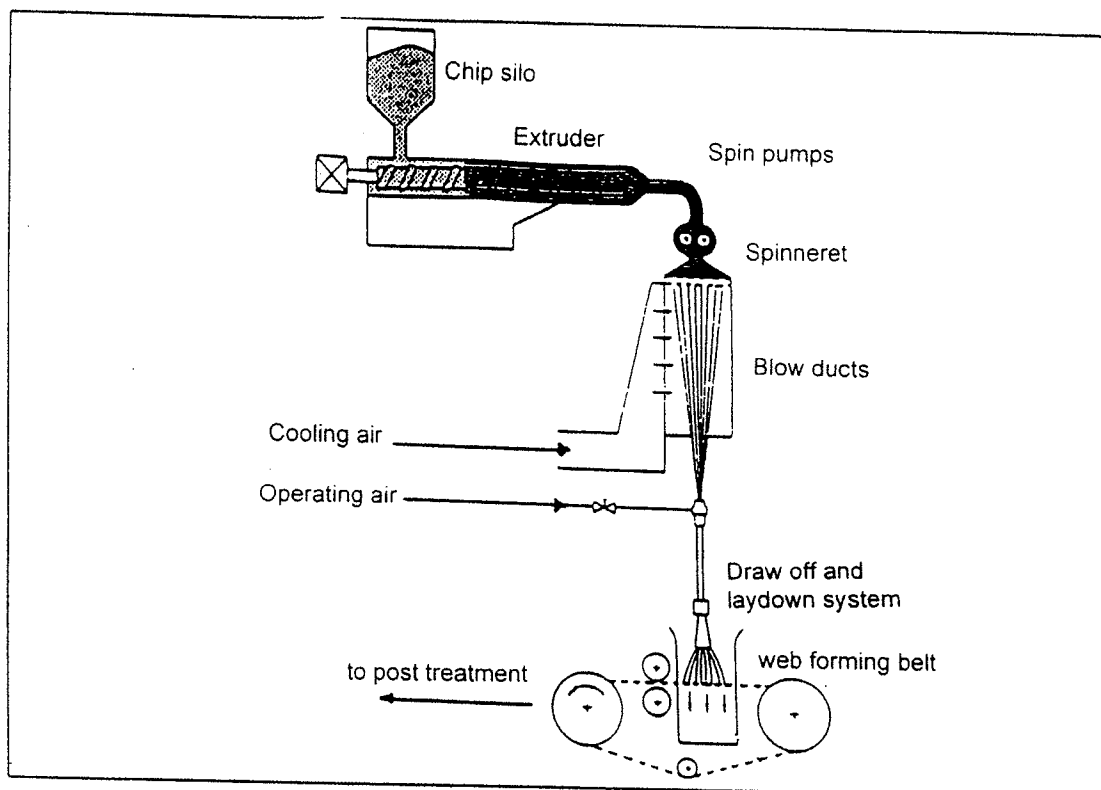


FIGURE 5.9 Lurgi-Docan Process

The principle involved in the Lurgi-Docan process is illustrated in Figure 5.9. The extended filaments are cooled and solidified by cross flowing quench air and are then taken up by tertiary (compressed) air.

Dependent on the filament size (dpf) and the polymer used the operating conditions will vary as shown in Table (5.1)

It can be seen that polypropylene requires a longer quench zone than polyester to produce the same dpf.

The Lurgi-Docan process technology was acquired by Zimmer and is the basis for their NST technology developments.

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Dpf	Ends/ nozzle	Take-up speed m/min	residual elongation % PET	residual elongation % PP	Quench zone length PET m	Quench zone length PP m
2	200	5000	130	140	0.6	1.2
5	120	4000	140	180	0.9	1.9
9	90	3200	180	220	1.20	2.4

TABLE 5.1 Lurgi-Docan Operating Conditions.

Reifenhauser GmbH

In 1984 Reifenhauser made public their developments of a 'short spin' technology which became known as the 'Reicofil' Process.

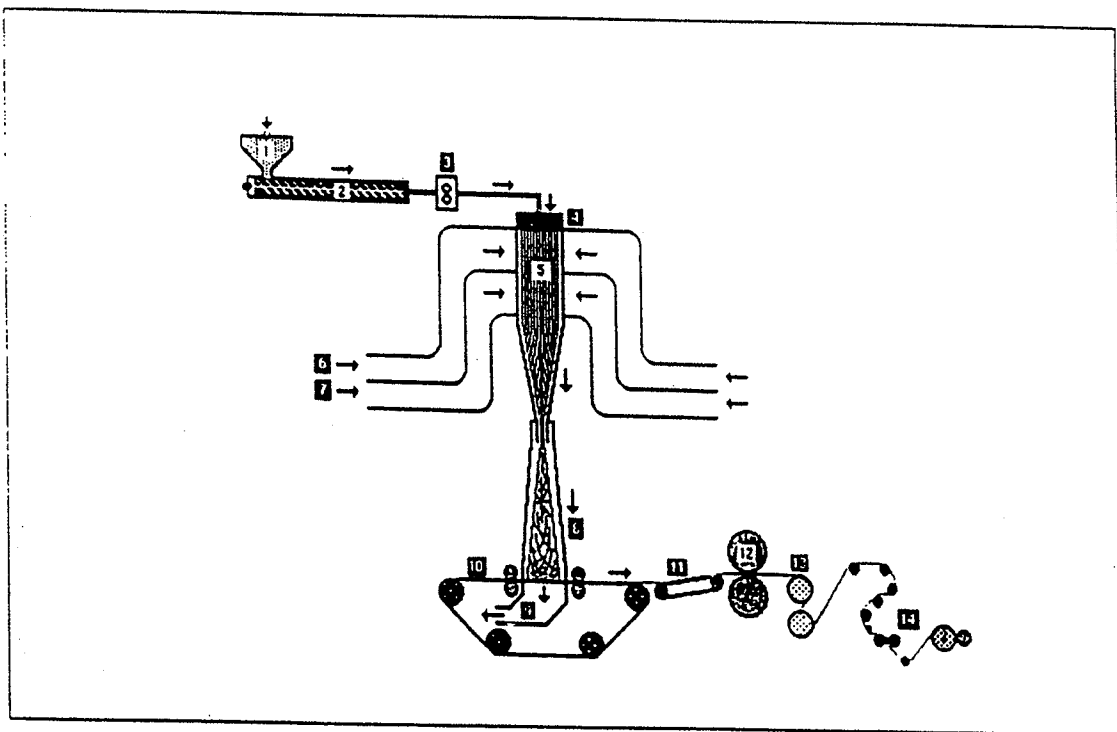


FIGURE 5.10 Schematic 'Reicofil' Process

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KEY to Figure 5.10.

- | | |
|------------------------------------|-----------------------|
| (1) Hopper | (8) Filament Entangle |
| (2) Extruder | (9) Suction Blower |
| (3) Spin Pump | (10) Spin Belt |
| (4) Die Block | (11) Guide Belt |
| (5) Cooling and Stretching Chamber | (12) Thermal Calender |
| (6) Cool Air Blower | (13) Chill Roll |
| (7) Auxiliary Air Blower | (14) Winding Unit |

Following on from the Reifenhauser developments, systems were offered by

S.T.P. Impianti, Italy
 Meccaniche Modern SpA, Italy
 Nonwovens Technology SpA, Italy
 Karl Fischer GmbH, Germany
 O.R.V. SpA, Italy

and others, but it should be noted that much of this early development was driven by the requirement for low grammage coverstock materials made from **Polypropylene**.

All suppliers at one time or another **claimed** to be able to process **Polyester** as well, but early installations for dual polymer based products, were all unsatisfactory and none were fully commercialised.

The **Fiberweb** Lurgi-Docan installation in Sweden has never made commercially, polyester based roofing, although it was designed to do so but it was found impractical to change.

The Lurgi-Docan system at **Polyfelt** has been, and continues to be, extensively modified from the original technology licensed.

Some of the process variables that have to be optimised are shown in TABLE 5.2.

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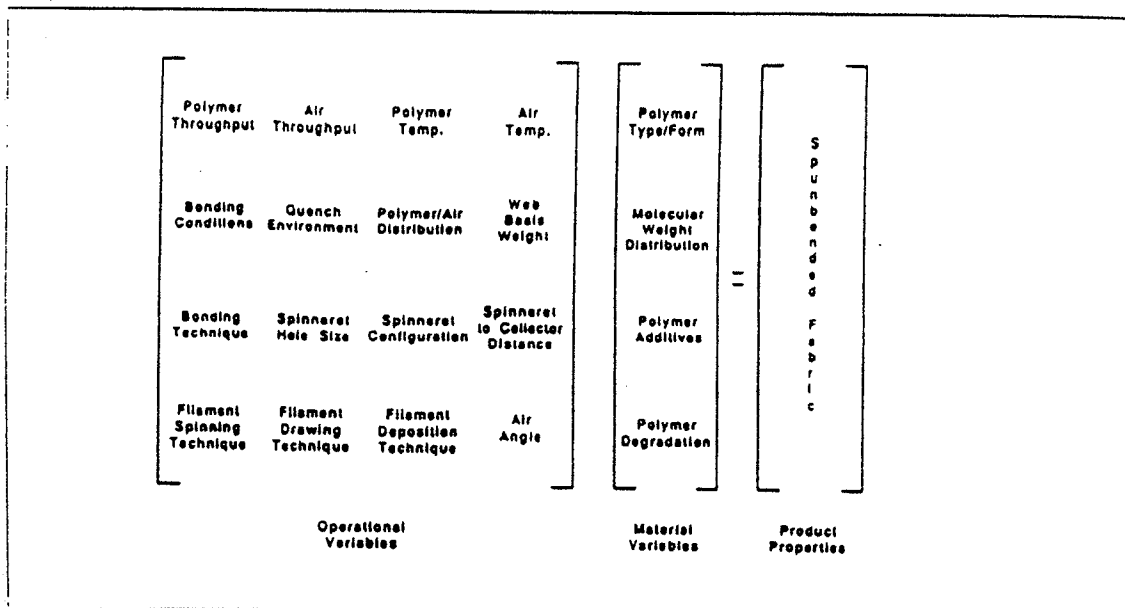


TABLE 5.2 Spunbond Process variables

Recent Developments in Spunlaid Technology.

Since 1990 there have been a steady flow of process developments to improve the web quality and productivity of the spunlaid process. Some of these developments are proprietary, some are developments of existing 'turnkey' systems, whilst others have started from the basic melt spinning process and have developed new alternative systems.

Developments from web production companies.

Two in-house developments illustrate this type of product:-

- i) 'Multidenier' by Corovin
- ii) 'S-Tex' by Fiberweb (both companies are now part of the same Group)

Corovin 'Multidenier' grades were the result of development to establish a process which was flexible enough to produce a range of nonwoven webs for the then current and perceived future applications.

The flexibility was achieved through a composite technology of the two spinning and web forming technologies, namely spunlaid and melt blown.

These two technologies are complementary to each other. In PP spunlaid continuous filaments of about 20 micron were normally produced. The web formed was slightly irregular but of good strength even at low web weights.

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Conversely, PP melt blown webs were made up of 2 micron fibres/filaments which formed a very homogeneous web but the strength characteristics were poor.

Multidenier technology is the in-line combination of these two technologies, each technology imparting its own characteristics to the end product. As a consequence, a Multidenier web consists of continuous filaments with a certain amount of intermingled very fine melt blown fibres. By adjusting the amount of each fibre/filament type, a wide range of product parameters can be achieved.

Further development of the technology allowed an increase of the melt blown fibre content in some areas of the web and a decrease in others. This resulted in coverstock materials with inherent lateral barrier properties. This hydrophilic/hydrophobic quality is liquid permeable only in the central zone of a web designed for diaper coverstock, but repellent at both sides due to a higher content of melt blown fibres.

S -Tex (Fiberweb)

The process technology that differentiates this system from a conventional spunlaid plant is the draw system used.

The S-Tex system is based on a curtain or slot draw. This means that the filaments leave the spinneret parallel to each other and arrive at the lay down belt in the same relative configuration.

The filament speed is relatively low and this lack of speed limited the line speed in the initial production. If the line speed was increased the MD/CD ratio was adversely affected.

This is a technology aimed at quality of the web rather than output and in this respect it recognised that there is a market for such products.

Initial data released	Filament size	< 1.0 -5.0 dtex
	M/C speed	20 - 300 mpm
	Web weight	< 12 - 150 g/m ²

Developments based on existing spunlaid systems.

The Lurgi 'DOCAN' licensed process was amongst the initial technologies for producing spunlaid webs. The original systems were large, and by modern standards produced poor quality webs but they were a base technology available to any company who wished to take a licence.

Therefore a number of these large units were sold to companies (Kimberly-Clark, Mitsui, Fiberweb Sweden [Holmens Bruk] etc.) and for some these provided the starting point for some very effective in-house development.

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The arrival of Reifenhäuser in 1984 with their 'Reicofil' process based on patents and research conducted in East Germany, introduced a more compact, less expensive but less flexible modular spunlaid system.

Despite this, the Lurgi 'DOCAN' process became rapidly eclipsed by the 'Reicofil' system and there is no doubt that it proved very successful.

The 'DOCAN' technology was maintained within the Lurgi Group and with the acquisition of Zimmer AG into the Lurgi Group development work on the 'DOCAN' system was restarted.

This resulted in the Zimmer NST system which was based on the original 'DOCAN' concept but with some significant changes aimed at removing some of the well known problems associated with the 'DOCAN' technology namely:

- the uniformity of polymer distribution in the spinning zone.
- the 'bunching' effect in the DOCAN draw-off jet resulting in unstable flow in the draw off tube.
- the poor filament distribution at the laydown point.
- the major changes required in the quench system to accommodate different polymers i.e. Polyester and Polypropylene.

With the exception of the quench system, the new NST technology has addressed these problems.

As far as we know, at this time, there is one production scale machine operating this new NST system and this is located at Jiangxi Heda Nonwovens Company Limited, Nanchang, China.

This machine is producing

Polyester, needled or thermobonded web for roofing or geotextiles.

Rated capacity 540 Kg/hr

Web weight range 50 - 450 g/m²

The quality of the web appears to be good and the company has had some success in selling the nonwoven material outside of the Chinese market.

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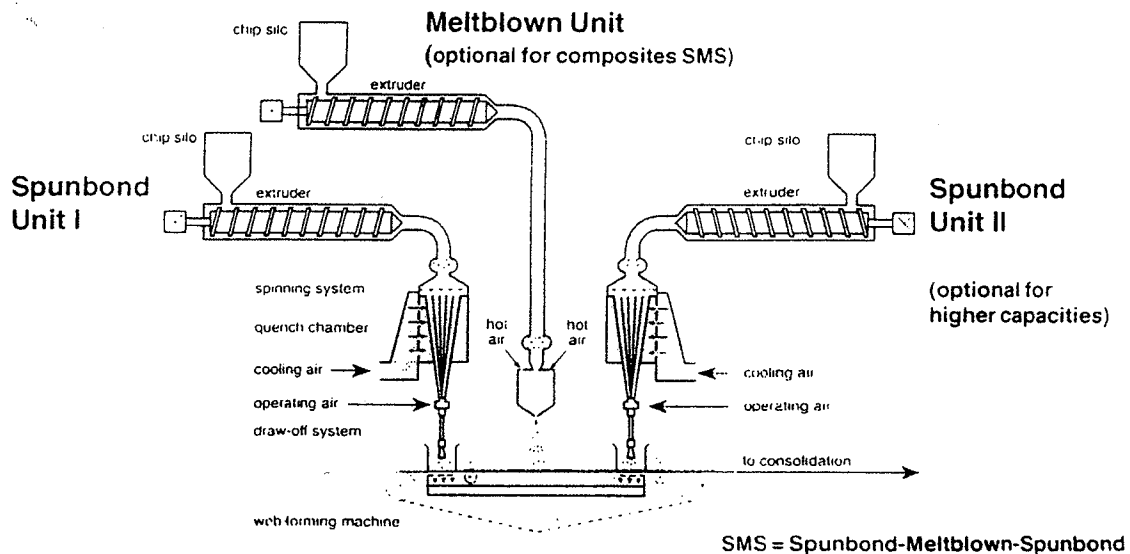


Figure 5.11 NST basic principle for SMS and high capacity production.

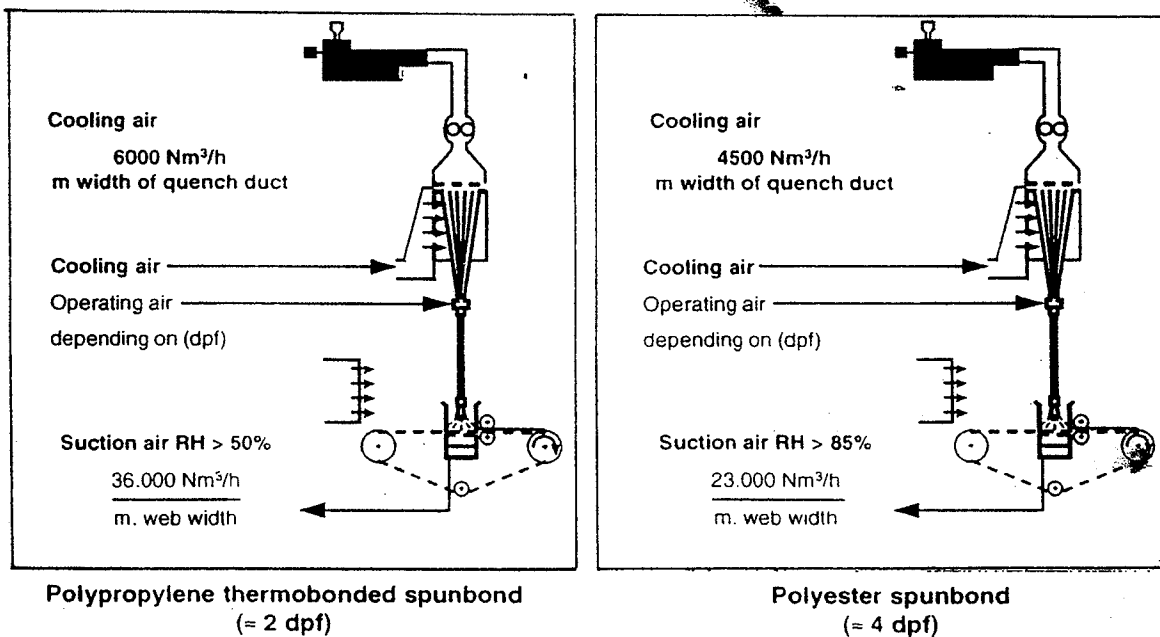
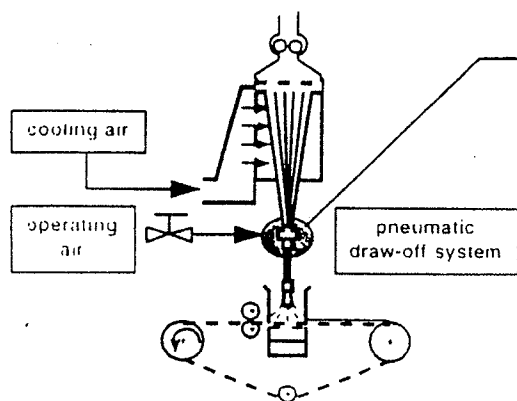


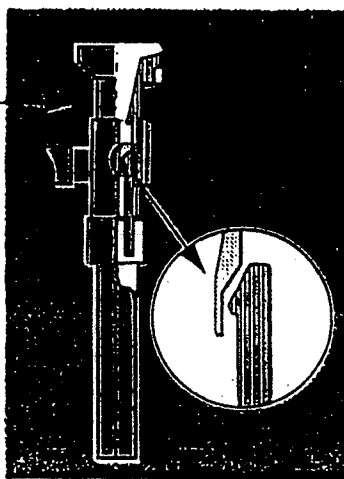
Figure 5.12 Polypropylene and Polyester basic operating parameters.

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Overview

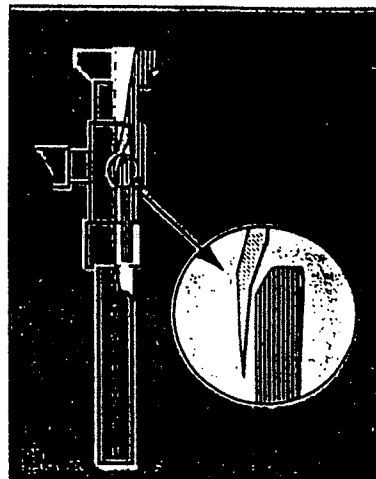


LURGI-DOCAN jet



- conventional type
- fairly adjustable

NST jet



- reduced air consumption
- improved adjustability

Figure 5.13 Zimmer redesigned draw jet.

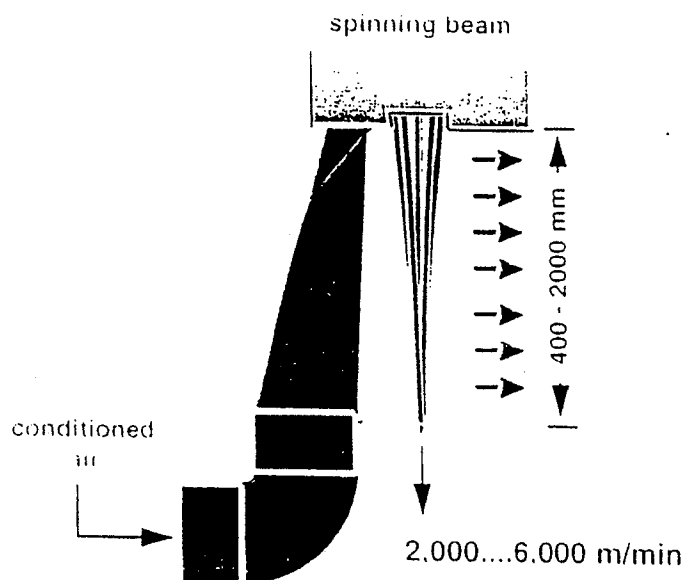


Figure 5.14 Zimmer NST Quench System.

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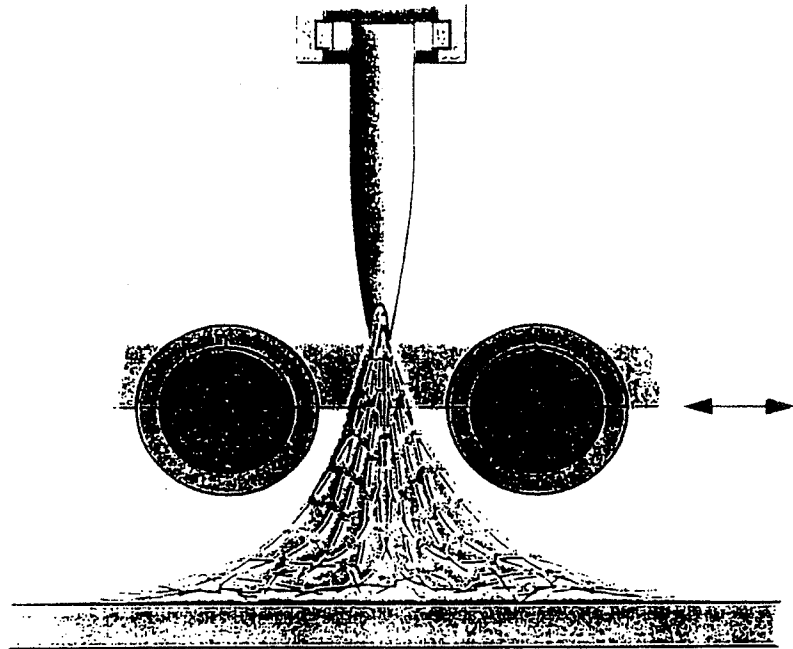
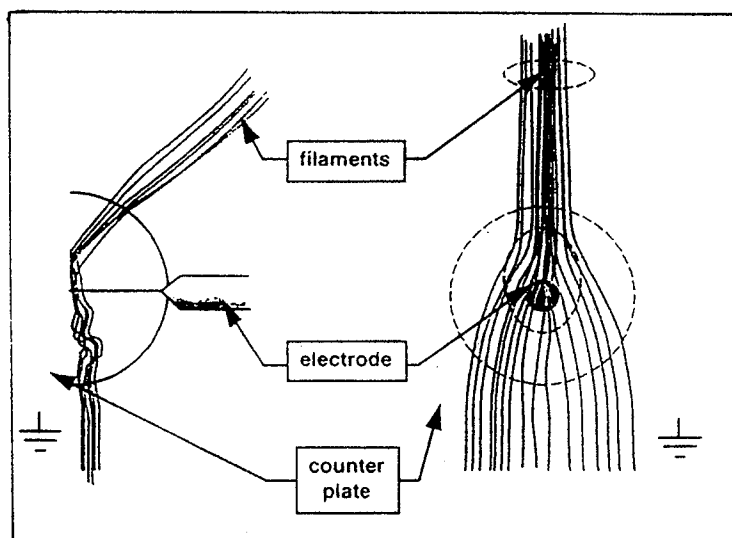


Figure 5.15 Zimmer NST - Coanda Oscillating Laydown Device.



- ◆ electrostatic devices increase the separation and the distribution of the individual filaments
- ◆ especially for light weight spunbonds

Figure 5.16 Electrostatic Filament Separation.

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Reifenhauser GmbH.

The original 'Reicofil' process has been very successful in terms of the number of units sold with over 100 machines having been installed world-wide since its introduction in 1984.

The original process has been adapted to changing needs and Reifenhauser now offer a number of variants such as 'Reicofil 3', 'Reicofil PET', and 'Reicofil MF' (micro filament). Many of these are new and as yet there is little information about the performance of the variants in commercial installations.

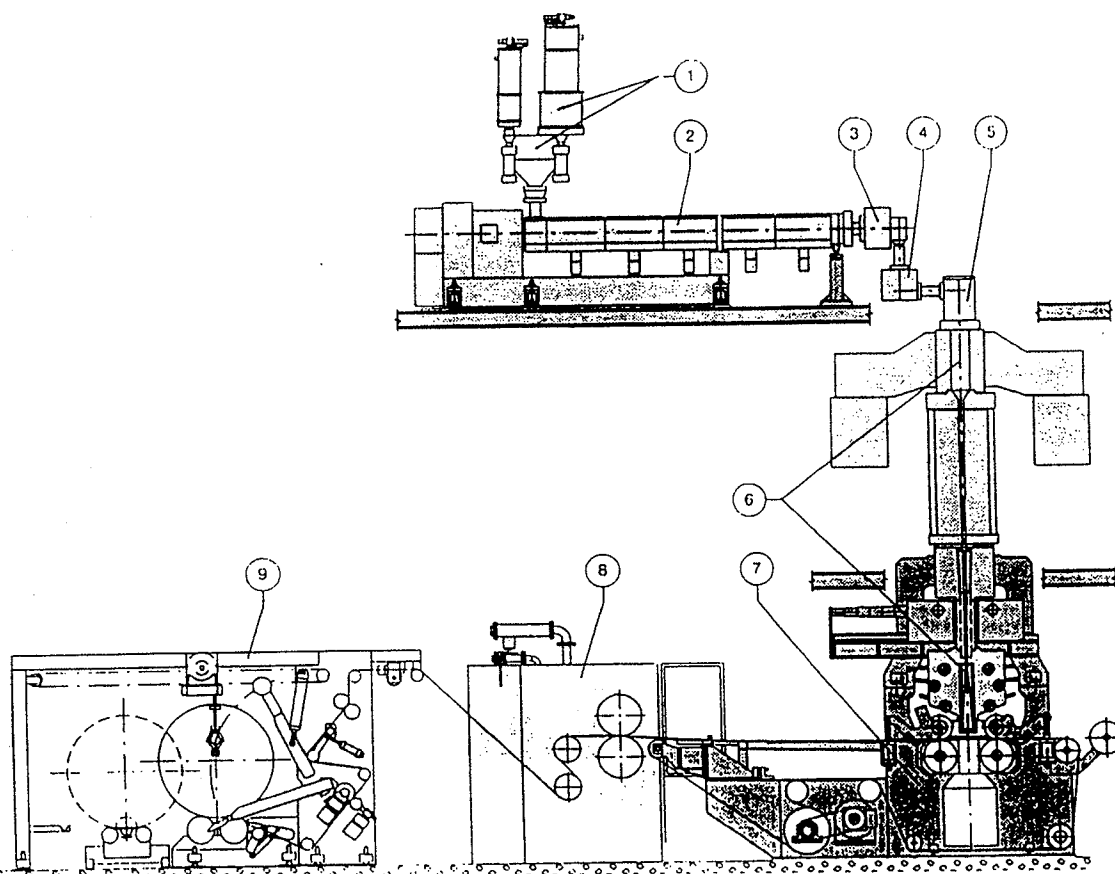


Figure 5.17 Reicofil 3 Spunbond system layout.

- | | | |
|-----|-------------------------|------------------------------|
| Key | 1 Material feed | 2 Extruder |
| | 3 Screen changer | 4 Spin pump |
| | 5 Filament forming slot | 6 Cooling and treatment zone |
| | 7 Laydown belt | 8 Calender |
| | 9 Winder | |

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'New' Developments - newcomers to the supply of spunlaid plant.

KOBE STEEL Limited.

The agreement that linked KOBE Steel with Kodoshi was terminated towards the end of 1997, and now both companies are independently offering spunbond equipment.

At this time the KOBE plant appears to be basically of the same configuration as that offered in the joint venture. KOBE are now claiming to have achieved 300 mpm line speed, below 1.0 dtex filaments (PP) and are progressing towards 500 mpm and bicomponent capability.

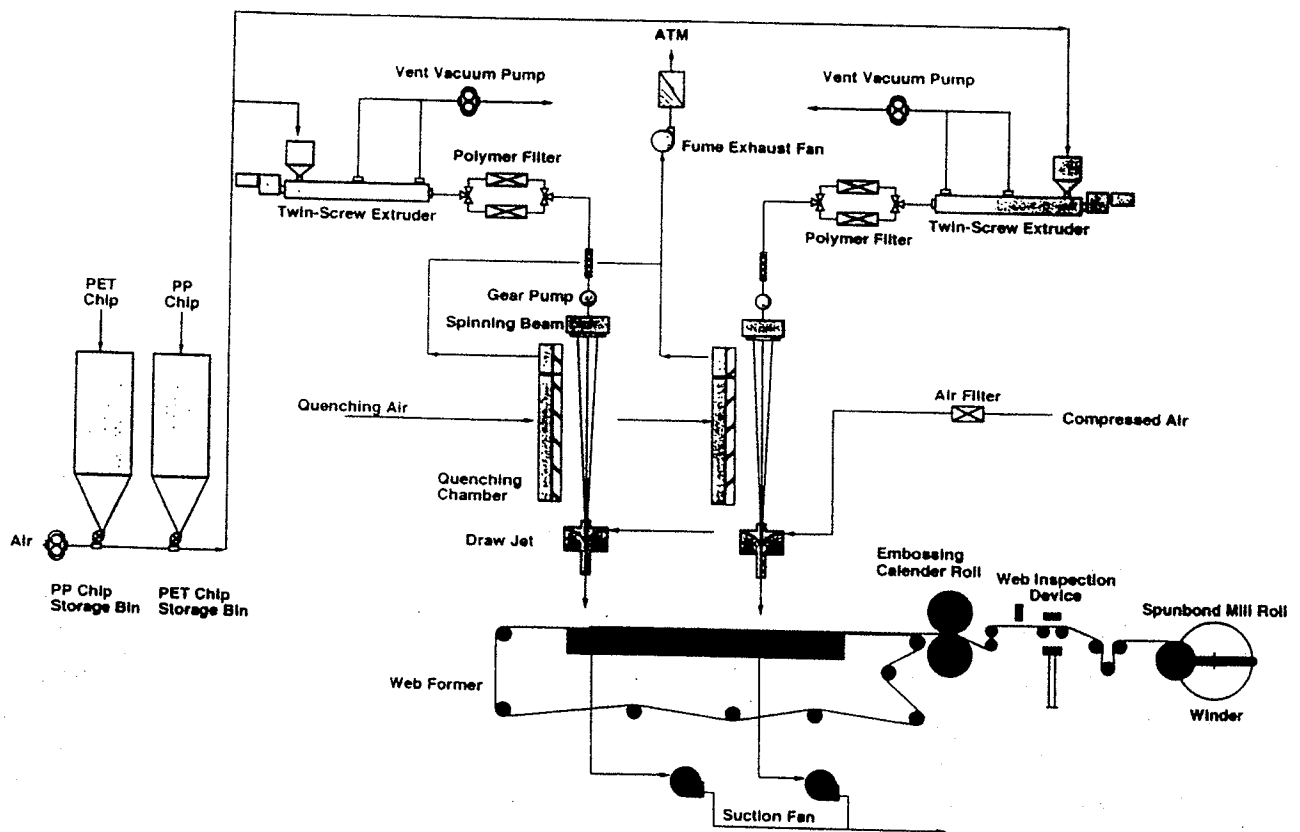


Figure 5.18 KOBE STEEL Limited Dual Polymer spunlaid system.

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Nippon Kodoshi Corporation.

With the termination of the joint venture agreement between Kodoshi and Kobe, both companies are offering spunbond systems

The Kodoshi system is said to have multipolymer capability, being able to process PP, PET, PE, PA, and PLA (biodegradable resin) on the same plant.

High speed spinning capability
Fine filaments
Line speed
Compact and economical line
Easy operation

up to 6000m/min
0.5 denier on PP
500 m/min
Low investment cost

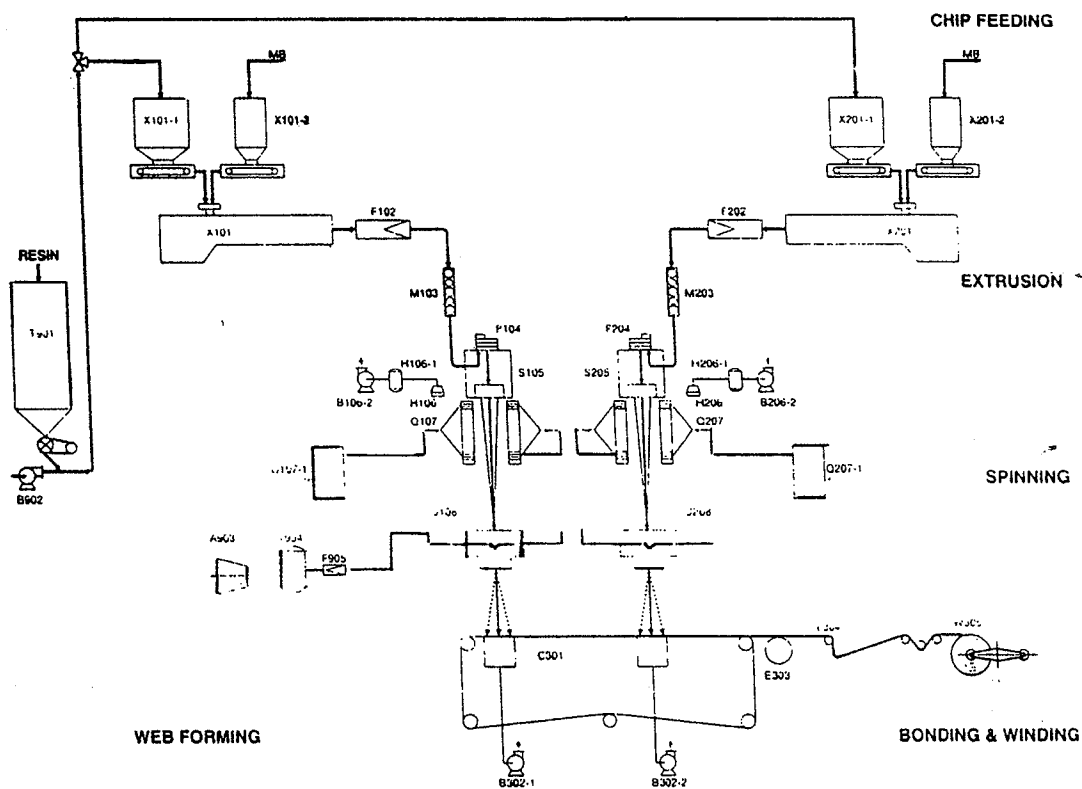


Figure 5.19 Kodoshi Spunbond System layout.

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ASON ENGINEERING INC.

ASON have developed a low pressure spunlay process with a slot drawing system and a novel melt spinning technique which permits much higher spinning velocities and allows the production of a wide range of different webs from different polymers and in differing filament configurations i.e. monofilament, bicomponent, and tricomponent.

The ASON system development started with a comparison of the two melt spinning technologies, spunlaying and melt blown, which have many similarities but also have significant differences.

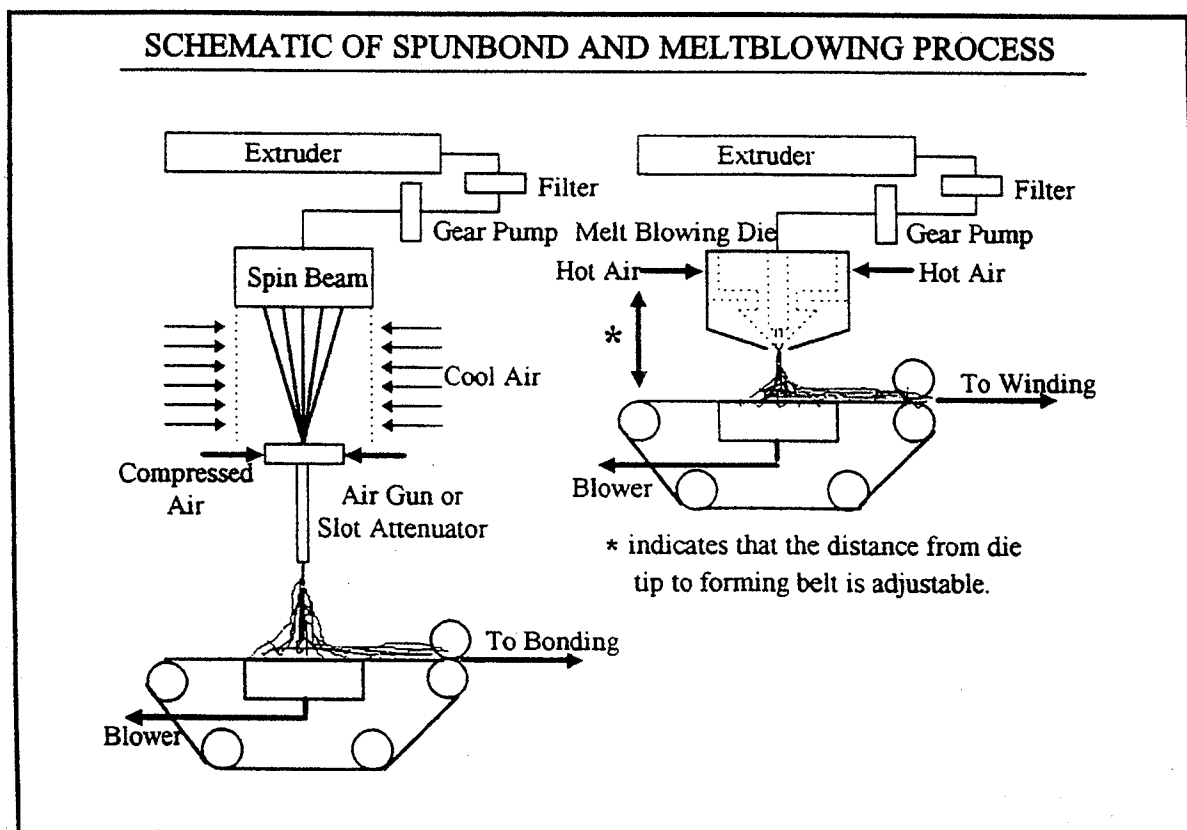


Figure 5.20 Comparison of Spunbond and Melt blown technology.

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Characteristics associated with each technology are as follows:

	Spunbond	Meltblown
Processing:		
Material (PP)	Low (35MFR)	High (800 - 1500 MFR)
Processing temp	Low	High
Filament temp	Rapid cooling by chilled air	Kept high by heated air stream
Quench chamber	0.5 - 3.0m, over cooling	Quench by ambient air, under cooling
Spin length	Very long (3 - 4m)	Extremely short
Forming distance	Fixed between draw device and laydown belt in a range 50 -120 cm.	Variable from die tip to laydown belt. Optimal range 15 - 40cm.
Web Characteristics		
Filament denier (dpf)	>2	<0.5
Fabric strength	High	Very low
Fabric uniformity	poor to moderate	Very good
Production rate (Kg/hr/m)	100 -200 at 2 - 6 dpf	30 - 70 at 0.1 - 0.5 dpf

	<u>Under-pressure</u>	<u>Low-pressure</u>	<u>High pressure</u>	<u>ASON</u>
Raw materials	PP	PP PET	PP PET	PP PET
Filament velocity (m/min) at 2-3 dpf	1,000-2,500	3,000 [3,500] [4,500]*	3,500 4,000	5,000 7,000
Production 0.5-1 dpf (kg/h/m) 1-2 dpf 2-3 dpf	150-180	~[70-100 100-150] ~150-200 [200-250]	~80-120 120-180 ~160-220 240-330	70-120 100-180 120-240 180-360 240-360 360-540
Filament strength	Low	Medium	Medium	High
Basis weight (gsm)	5-100	5-500	5-500	5-500
Fabric uniformity	Poor	Poor	Poor	Good
Building height	10m	10m [14m]	20-25m	6m
Investment cost (US\$/Kg/year)	3.6	2.1 [4.5]	2.8	1.2
Energy cost (kwh/kg)	2	2.2 [3]	5	1.5

Comparison of main types of spunbond system with ASON.

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	Spunbond	ASON	Meltblown
Spin Length (m)	3.0 - 4.0	0.3 - 1.0	<0.1
Filament temp. before drawing	Ambient	High	Extremely high
Mechanism of drawing force	Viscous friction	Viscous friction + form drag	Form drag
Forming distance	fixed	variable	variable
Filament velocity PP (m/min)	<3000	4000 - 6000	>> 10,000
Filament denier	>2	0.5 - 2	<0.5
PP production rate (kg/hr/meter width)	100 - 180 (2-3 dpf)	240 - 300 (2-3 dpf)	50 - 70 (0.1-1.5 dpf)
Fabric strength	Medium	High	Low
Fabric uniformity	Median	Good	Good
Production cost (\$/kg)	Medium	Low	High

Comparison of Process and Product Characteristics.

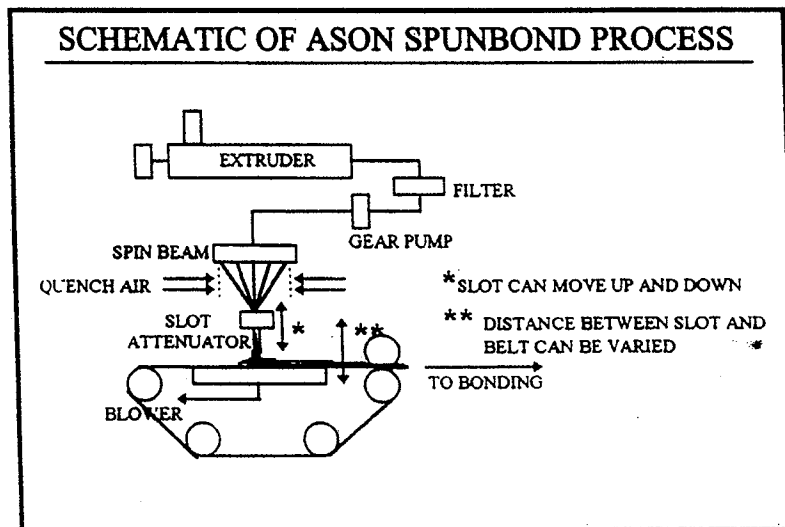


Figure 5.21 Schematic of ASON Spunbond process

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The ASON process uses a slot attenuator with low air pressure (1 - 4 bar).

The unique characteristics of the ASON system are the adjustability of two distances: the distance between the spinneret and the slot and the distance from the slot to the forming belt.

There are four areas where the ASON technology is derived and to some extent simulates meltblown technology:-

- | | |
|------------------|---|
| Spinline: | Very short spin line with variability of its length, defined as the distance from the spinneret to the drawing device.
Spinning speed 4000 - 6000 m/min PP
4000 - 8000 m/min PET
Spin line length 0.3 - 1 meter. |
| Quench: | Short chamber is used to cool the filaments in such a way that the temperature of the filaments remains as high as possible along the entire spin line. |
| Drawing force | Mechanism of form drag is fully utilised along with viscous friction to achieve highest drawing force at lowest air pressure. |
| Forming distance | Adjustable distance between the slot and the laydown belt to obtain optimal web formation. |

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MELT BLOWN NONWOVENS**Introduction.**

Work on melt blowing owes its origins to the work by V A Wentz at the US Naval Research Laboratory in the 1950's. Motivation for this early work was the need to produce microdenier (less than 5 micron diameter) fibres for filter media.

Exxon Research and Engineering developed this early work but others (i.e. E Schwarz Biaz Fiberfilm) also contributed to the continuing development work. Exxon, through their association with the University of Tennessee, Knoxville, continue their association and support of work in this technology through to this day.

The first thing that needs to be recognised is that melt blown fibres/filaments are **very small**.

A human hair is about 120 decitex, a melt spun textile grade polyester filament is about 3 decitex.

Compared to these, a 2 micron melt blown fibre is 0.05 decitex.

This unique microdenier character of melt blown fibres is exploited in most of the uses to which this material is put.

The Process of Melt Blowing.

In conventional melt spinning, polymer is extruded into a gas, usually air, at ambient temperature.

The gas performs two functions:

- i) It cools the filaments
- and ii) Because of the rapid motion of the filament through the gas, the gas exerts a drag force on the filament.

In the melt blowing process, the gas performs a different task.

In melt blowing, a high velocity gas stream impinges on a molten polymer stream as the polymer extrudes from a small capillary in the melt blowing die.

The force of the gas rapidly attenuates the filament from about 500 micron diameter at the capillary down to diameters as small as 0.1 micron.

This is a 5000X reduction of fibre diameter and a 25,000,000X reduction in cross sectional area.

This process occurs in about 200 microseconds over a distance of about 3 cm.

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In the melt blown web, this amounts to six times more surface area and thirty six times more fibre in a melt blown web of 1 - 3 microns than in an equivalent fibre weight of a typical carded or spunlaid web

Raw Materials - Polymers for melt blowing.

In theory, any polymer that can melt without significant degradation of the polymer, could be a raw material feed stock for a melt blown web.

However, polymers with very high melting points, or which exhibit thermal instability at their melting point, have not been the subject of much commercial activity, although many have been investigated in research programmes.

Some companies (i.e. Kimberly-Clark with elastomeric webs) have succeeded in developing techniques to handle these more difficult materials.

The following polymers are some of many suitable for meltblowing.

- Polypropylene - Homopolymers and Copolymers
- Linear and Branched Polyethylene
- Ethylene Vinyl Acetate
- Ethylene Methylacrylate
- Polystyrene
- Thermoplastic Elastomers
- Polyesters
- Nylon
- Polyurethane
- Polycarbonate
- Polyphenylene Sulphide
- Blends of different Thermoplastics
- Bitumen

Desirable Resin Parameters

- Low Molecular weight/viscosity
- Narrow Molecular weight distribution
- Good web bonding characteristics
- Good solids handling
- Low cost/benefit ratio

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Other Resin Parameters sometimes needed

- End use stability
- Low odour
- Colour uniformity
- Ability to be pigmented
- Compatibility with other materials for composites and laminates.

Web Properties - General

- Microfibre web - 1 - 10 micron fibres
- Soft self bonded
- Excellent covering power, uniformity
- Basis Wt from 3 gm/m² to 1000 gm/m²
- Balanced properties - CD/MD from 0.5 to 1.0

Web Properties - Strength

- Sufficient strength for web handling, lamination, etc. and for many applications as is.
- Fibre strength approximately 0.33 gms/decitex
- Web strength - 0.05 to 1.6 KG/CM (35 gsm web) - depends on polymer, post bonding, etc.

Web Properties - Pore Characteristics

- Pore size from - 27 micron upward (as is) - 8 micron upward (calendered)
- Void fraction 20 - 85%
- Good wicking action for oils (also water if treated)
- Good water barrier with Polyolefins (as is)
- Accepts and holds electric charge - high filtration efficiency.

Process Parameters

- Die widths - up to 3.2 meters
- Specific die throughput - 0.3 - 0.7 KG/HR/CM (0.4 - 1.5 GM/MIN/Hole)
- Process temperature - 200 - 400⁰ C, depending on Polymer
- Die pressure - 50 KG/CM² Melt viscosity at die - 50-250 poise
- Air rate - up to 335 L/MIN per die CM
- Air pressure - up to 2 KG/CM² at die

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Resin	web type	web weight g/m ²	Tensile KG/cm	Air perm. cc/cm ² /sec	Max Pore diameter micron
PP	STD	15	0.2	78	40
PP	FINE	30	0.5	27	31
PP	FINE/CAL	50	0.8	4	13
PP	STD/CAL	50	0.8	10	40
PP	STD	200	3.6	8	35
NYLON 6	STD	50	1.2	30	45

TABLE 5.3 Typical properties of meltblown polymers

Process Limitations

- Shot formation - coarse particles produced at improper melt temperature or viscosity
- Roping - surface fibre bundling from excessive air amount/velocity along surface.
- Fly - loose, short fibres produced at too high temperature or too low viscosity

Advantages vs other nonwoven processes

- Unique fine fibre product
- Self bonding as formed
- Fibre breakage easily tolerated
- Wide range of resins can be used
- Accepts blends readily
- Low basis weight capability
- Uniformity of laydown

Disadvantages

- Low strength
- Low abrasion resistance

NONWOVENS TRAINING COURSE

New technology areas

- Elastomeric webs
- Composite materials - addition of powders/fibres
- Electrostatic charging
- Tubular products
- Engineering thermoplastics
- Resin blends
- Recycled resins
- Tailored polyolefin resins
- New types of dies
- Complete, fully integrated, compact lines.

Meltblown Product Applications

Ultrafine particle filters

Breathable protective apparel

- Surgical face masks
- Operating room drapes and gowns
- Sterilisable instrument wrapping
- Surgical Towels
- Barrier fabrics for agricultural and industrial workers

Battery Separators

Industrial wipes

Insulating batting

Tenting fabrics

Absorbent for oil spills

Personal hygiene products

Synthetic leather base materials

Adhesive webs

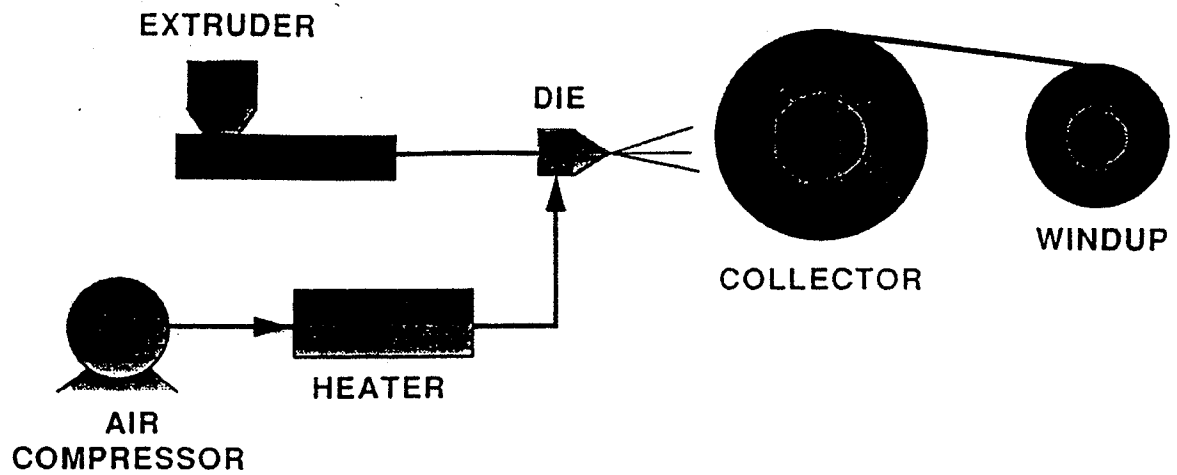


Figure 5.22 Schematic of Melt blowing Process.

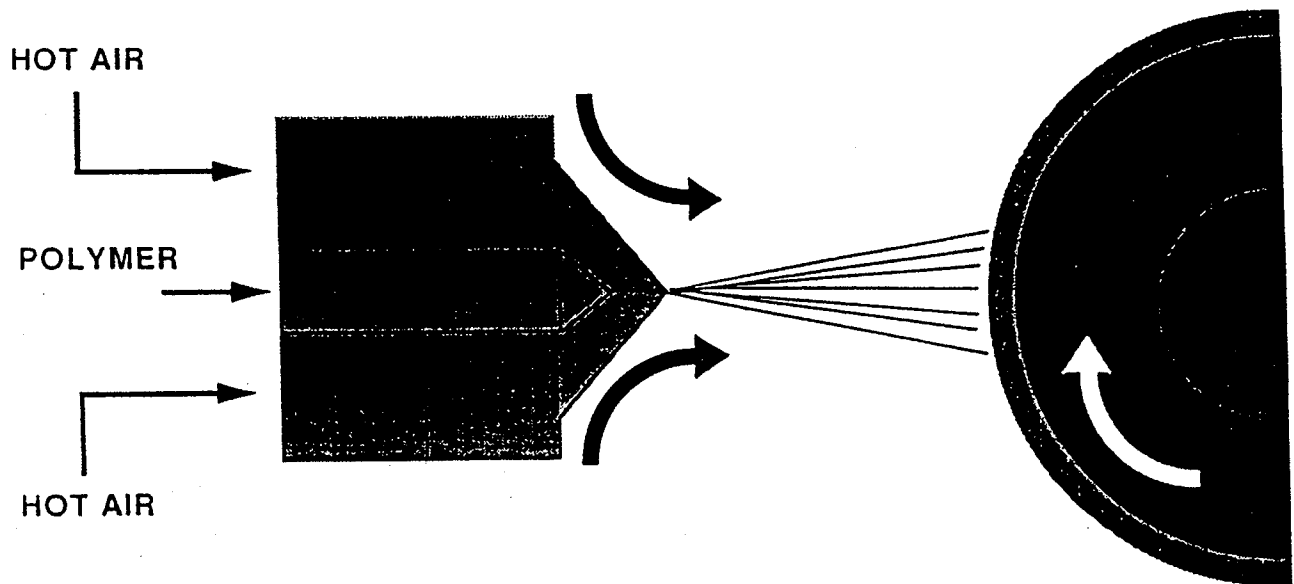


Figure 5.23 Schematic of Fibre Forming Process.

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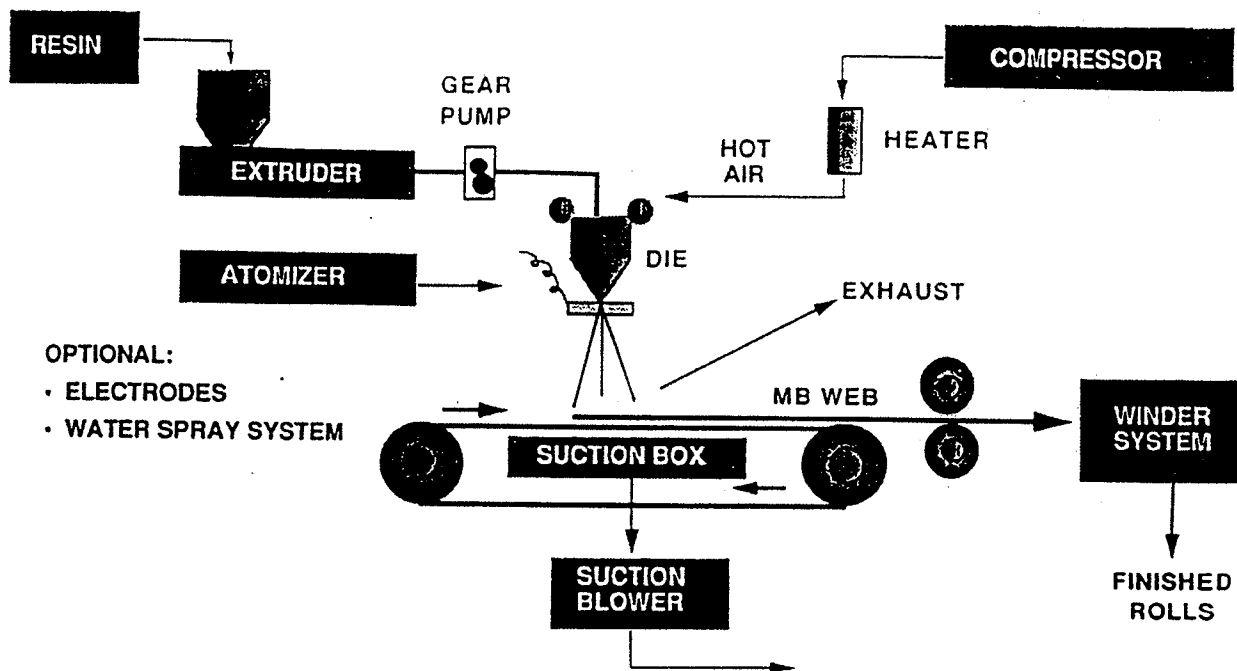


Figure 5.24 Complete melt blowing line.

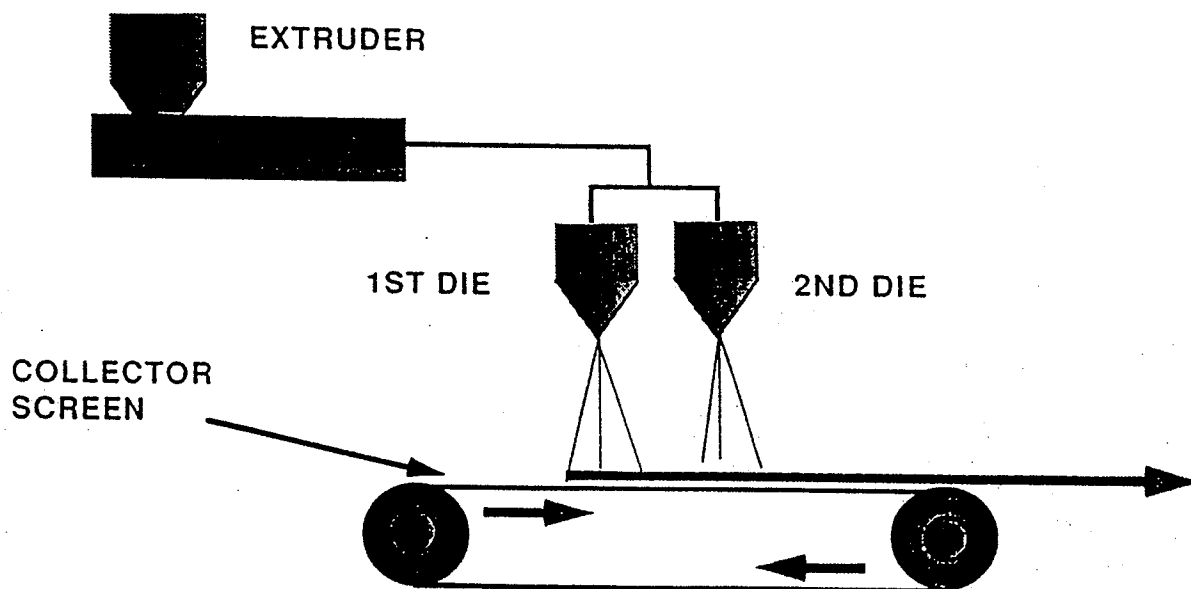


Figure 5.25 Multiple die melt blowing.

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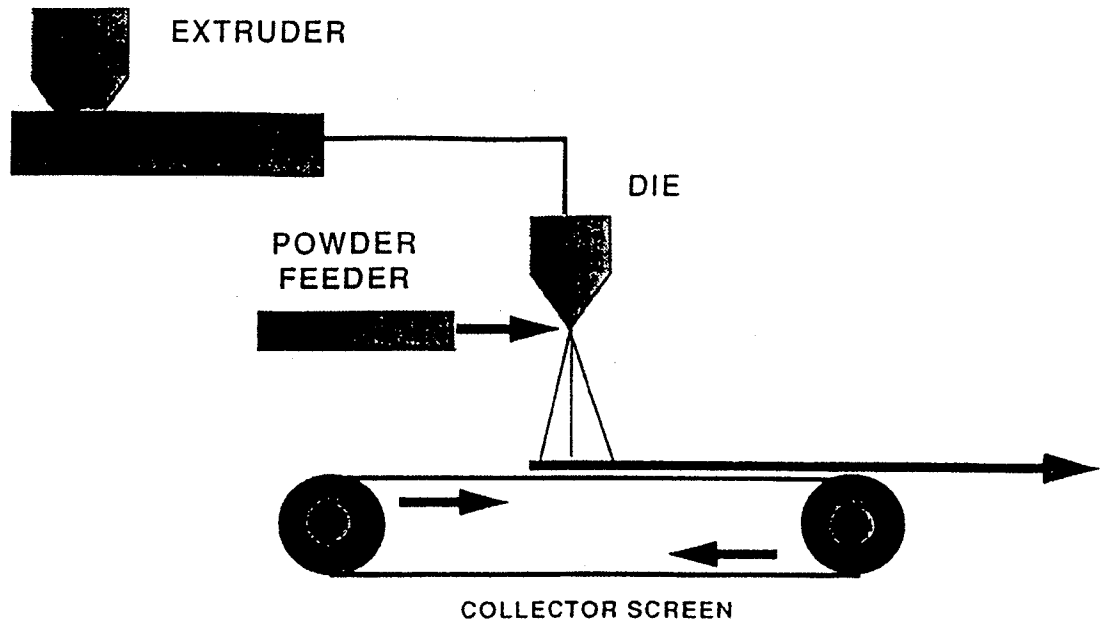


Figure 5.26 Powder or fibre addition process.

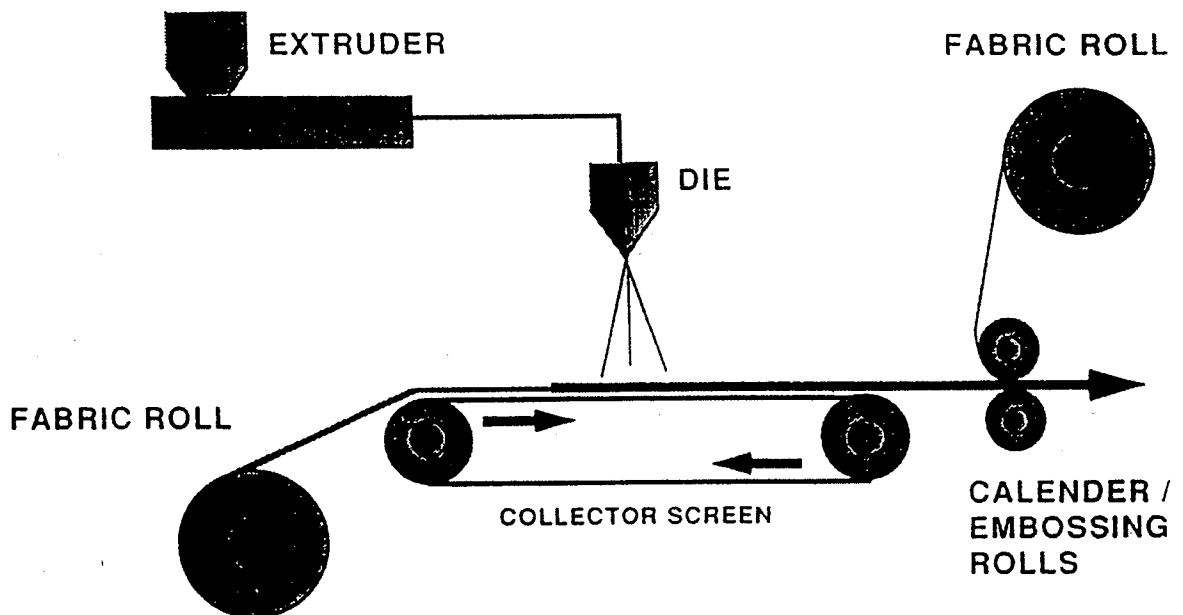


Figure 5.27 Lamination system.

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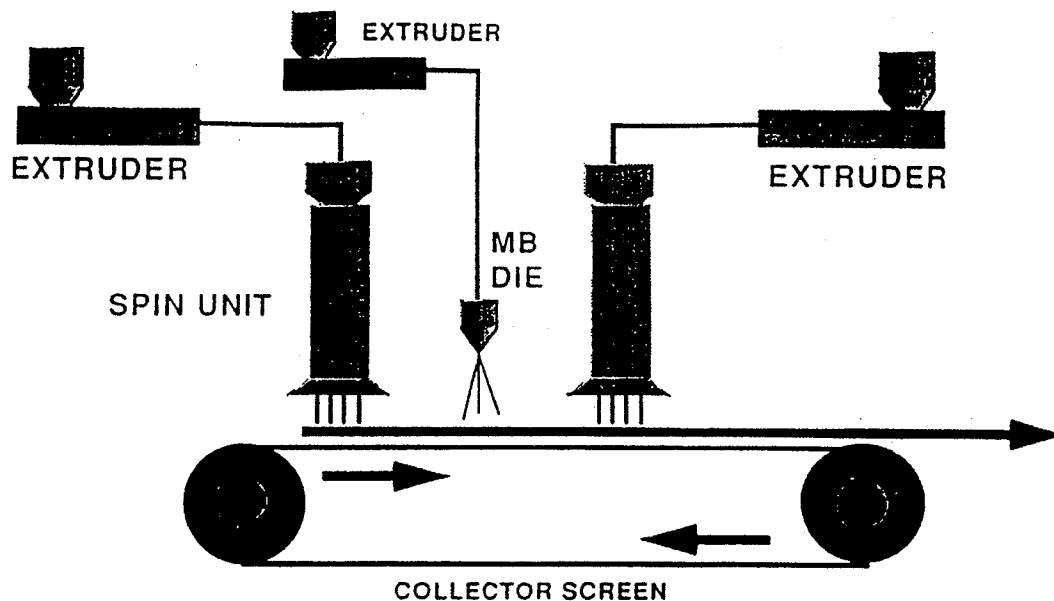


Figure 5.28 Spunbond/melt blown/spunbond (SMS) process.

SUMMARY Meltblown Nonwovens

The meltblown process is described as a single step production of a biaxially oriented thermoplastic nonwoven fabric of microdenier fibres produced by a combination of filament extrusion and hot gas attenuation into discontinuous fibres, which are 'frozen' and propelled onto a collection belt for web formation.

Web bonding is accomplished primarily by natural mechanical fibre entanglement, secondly from cohesive fibre forces and thirdly by thermal bonding if so required.

Process Parameters

The meltblown process may initially appear to be primarily a function of 'resin feed rate and temperature' and 'gas flow rate and temperature'.

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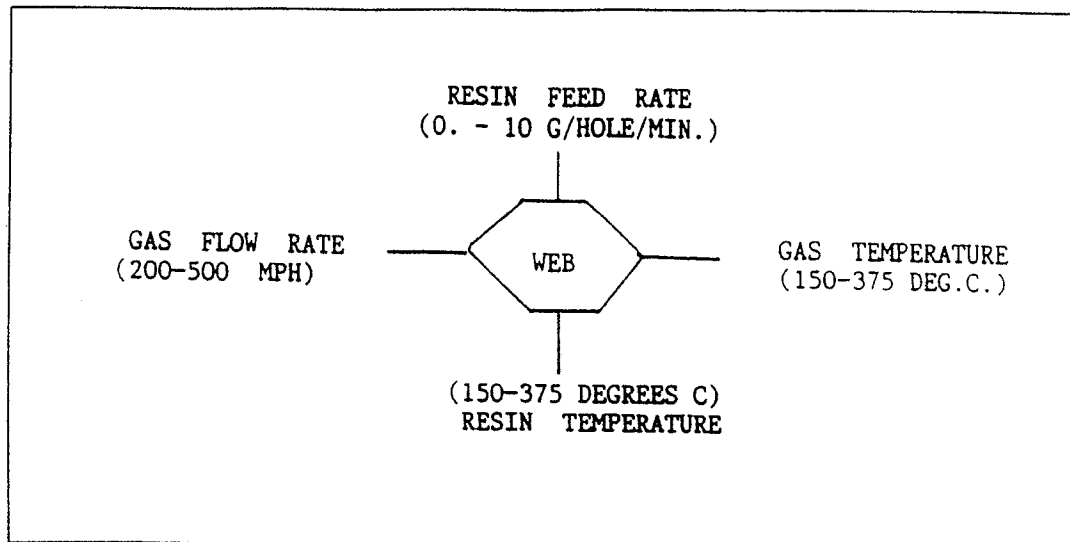


Figure 5.29 Primary Process Parameters.

Dealing with these parameters alone is not enough. The following must also be dealt with.

GAS VELOCITY	POLYMER SHEAR
KNIVES GAP	FILTRATION
SET BACK	DCD
POLYMER TYPE	QUENCH ENVIRONMENT
MOLECULAR WGT	GAS DISTRIBUTION
MELT VISCOSITY	FIBRE STREAM SLANT
MELT STRENGTH	WEB FORMER TYPE
POLYMER DEGRADATION	FIBRE/GAS SEPARATION

TABLE 5.4 Contributory Process Parameters.

Each one of these elements are significant contributors to process performance and product variability. They need to be precisely defined and understood to master the meltblown process.

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Meltblown Nonwovens in Filtration

An area where the advantages of melt blown materials have been exploited is that of **Filtration**.

The Japanese company Toray have produced a typical melt blown nonwoven filter material, the properties of which are shown below:

Properties of Toraymicron-E

		Toraymicron Type-E	(cf.) Glass Filter	
			HEPA	ULPA
Thickness(mm)		0.63	0.44	0.43
Weight(g/m ²)		100	75	76
Porosity(%)		82.6	92.3	92.0
Collection Efficiency (%)	0.1μm	99.9997	99.98	99.9995
	0.3μm	99.9999<	99.9961	99.9999
Pressure loss(mmAq)		8.0	17.0	24.0

Comparison of the Toray meltblown material with conventional glass micro fibre media is shown:

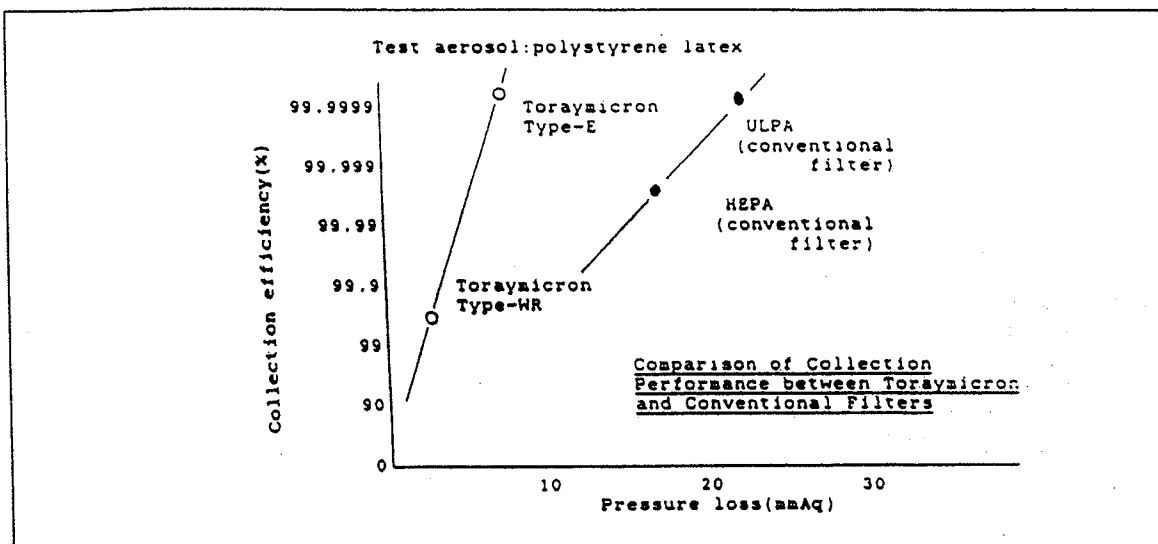


Figure 5.30 Efficiency/Pressure drop of Electret Melt blown filter.

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Electrostatic Melt Spinning

Introduction

The forming of fibres and nonwoven webs by the action of a high voltage electrostatic field on molten thermoplastic polymers was developed in the 1970's at the Battelle Institute, Geneva.

The process has become known as electrostatic melt spinning (EMS) and it produces electret (that is charged) fibres in the 1-20 micron fibre diameter range.

The process involves applying a uniform coating to a cylindrical emitter electrode of a thermoplastic polymer. This melted polymer is subjected to an electrostatic field produced between the emitter electrode and a flat-plate collector electrode.

Polymer fibres are generated by the emitter electrode along the line of electrostatic force.

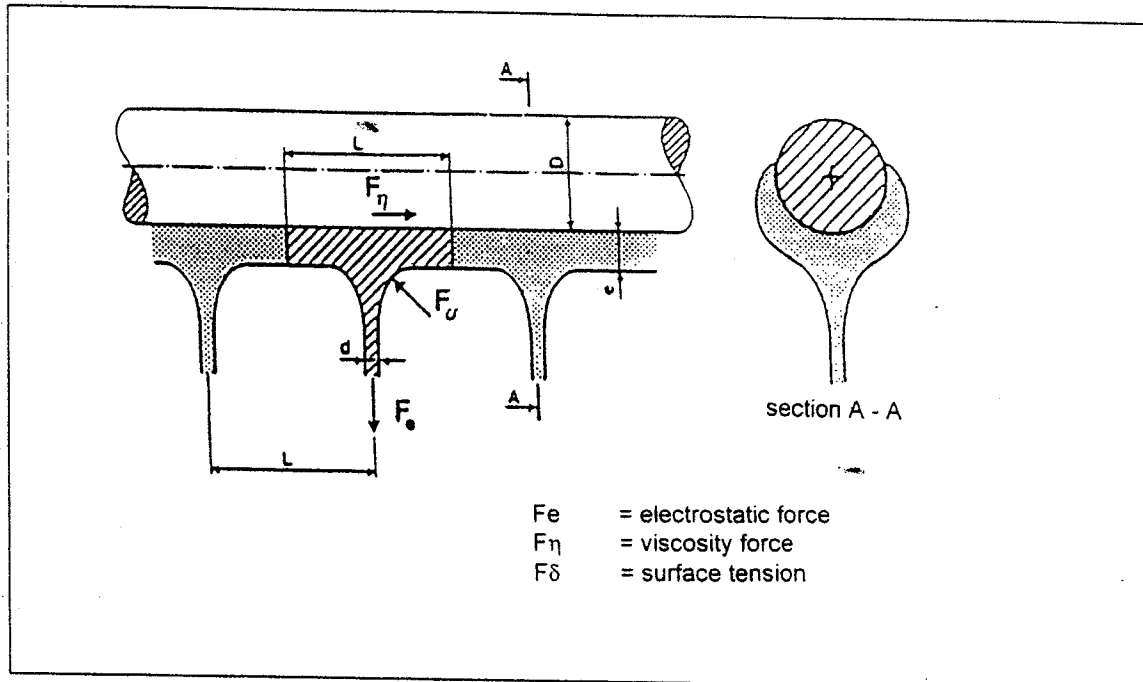


Figure 5.31 Electrostatic forces acting on the material covering the wire.

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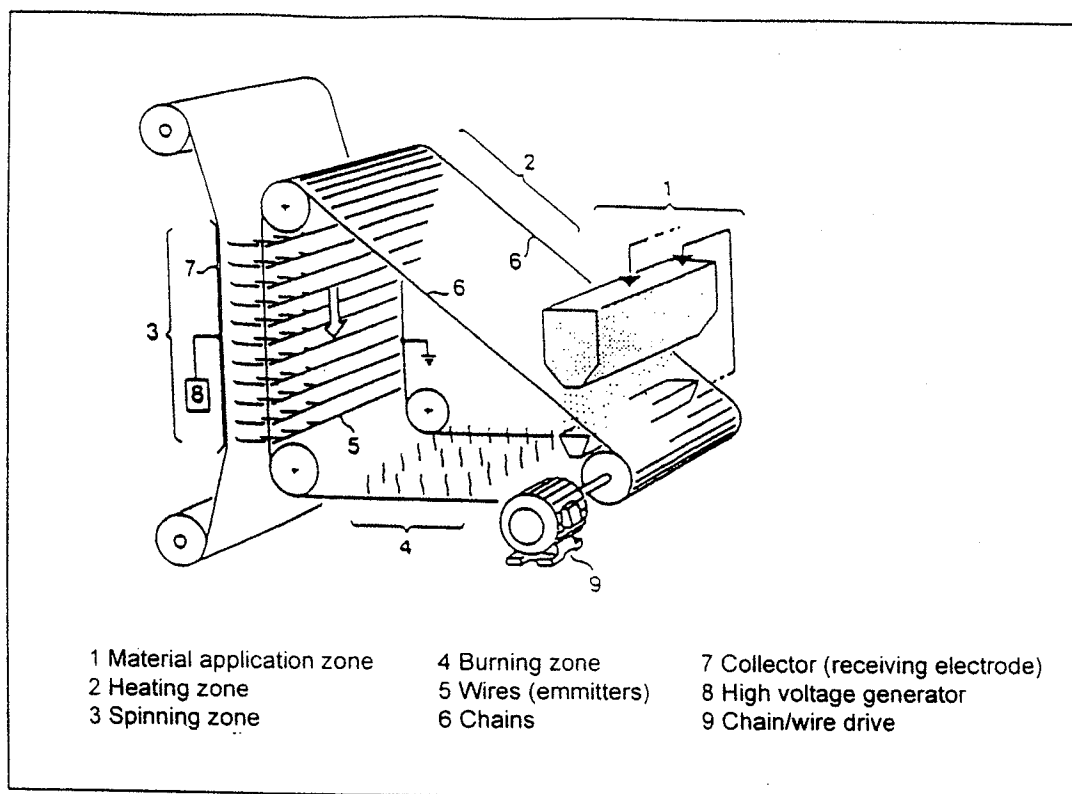


Figure 5.32 Diagram of a wire machine.

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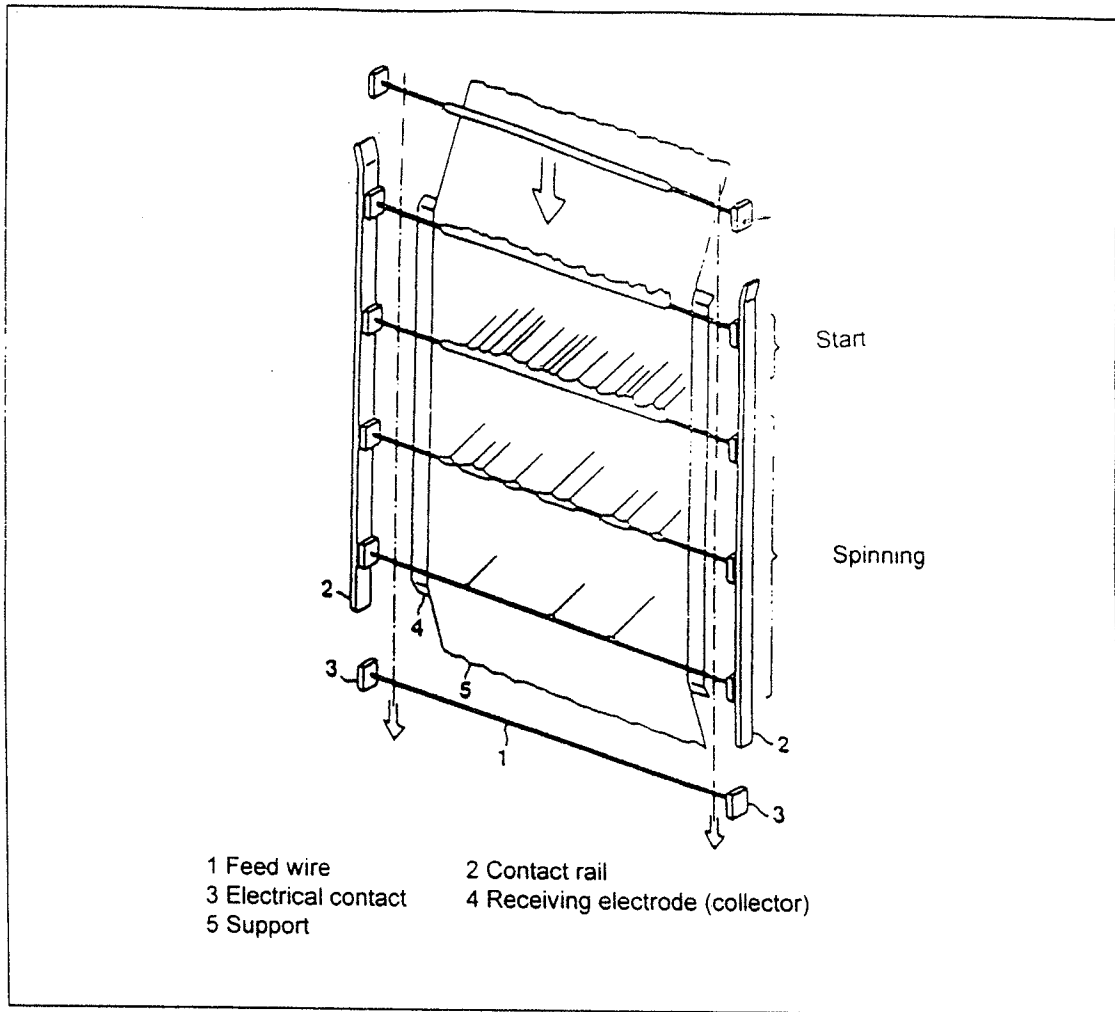


Figure 5.33 Spinning operation.

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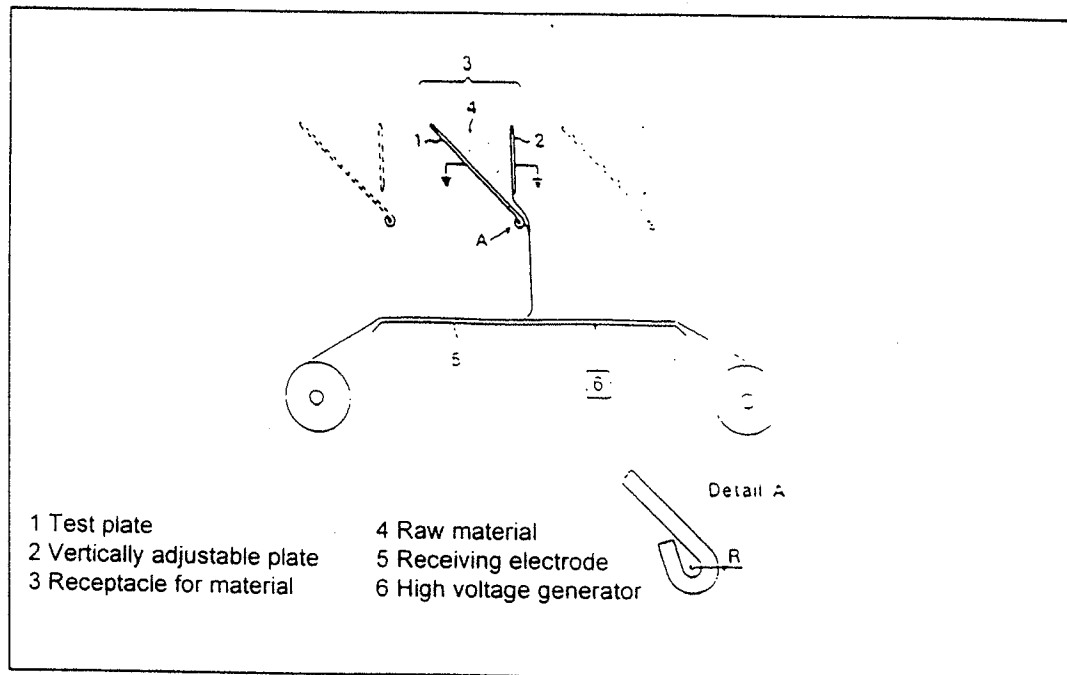


Figure 5.34 Diagram of a Heated Plate machine.

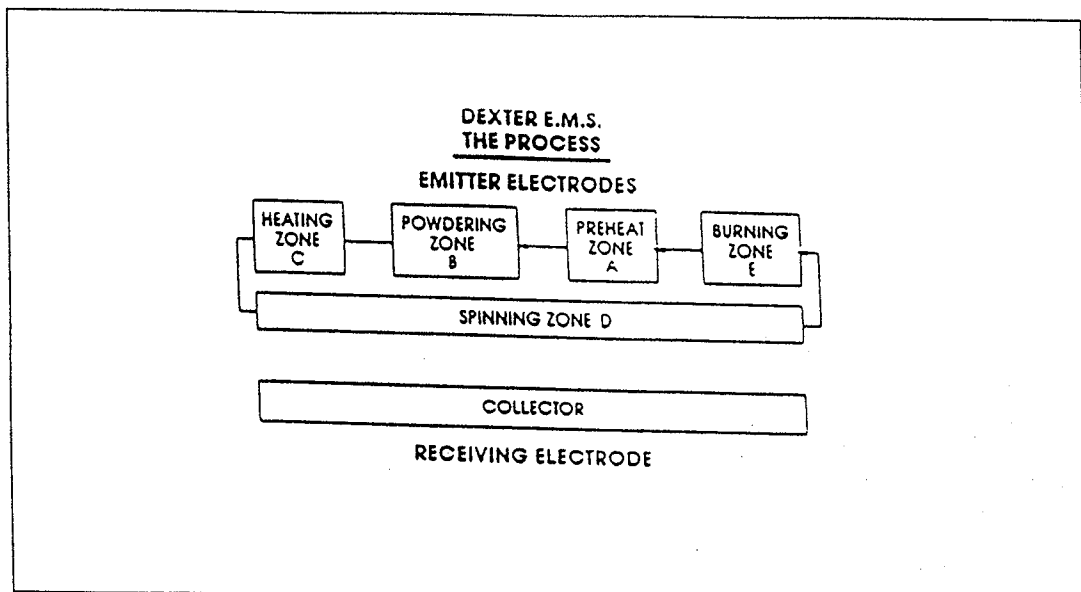


Figure 5.35 The Dexter E.M.S. Process.

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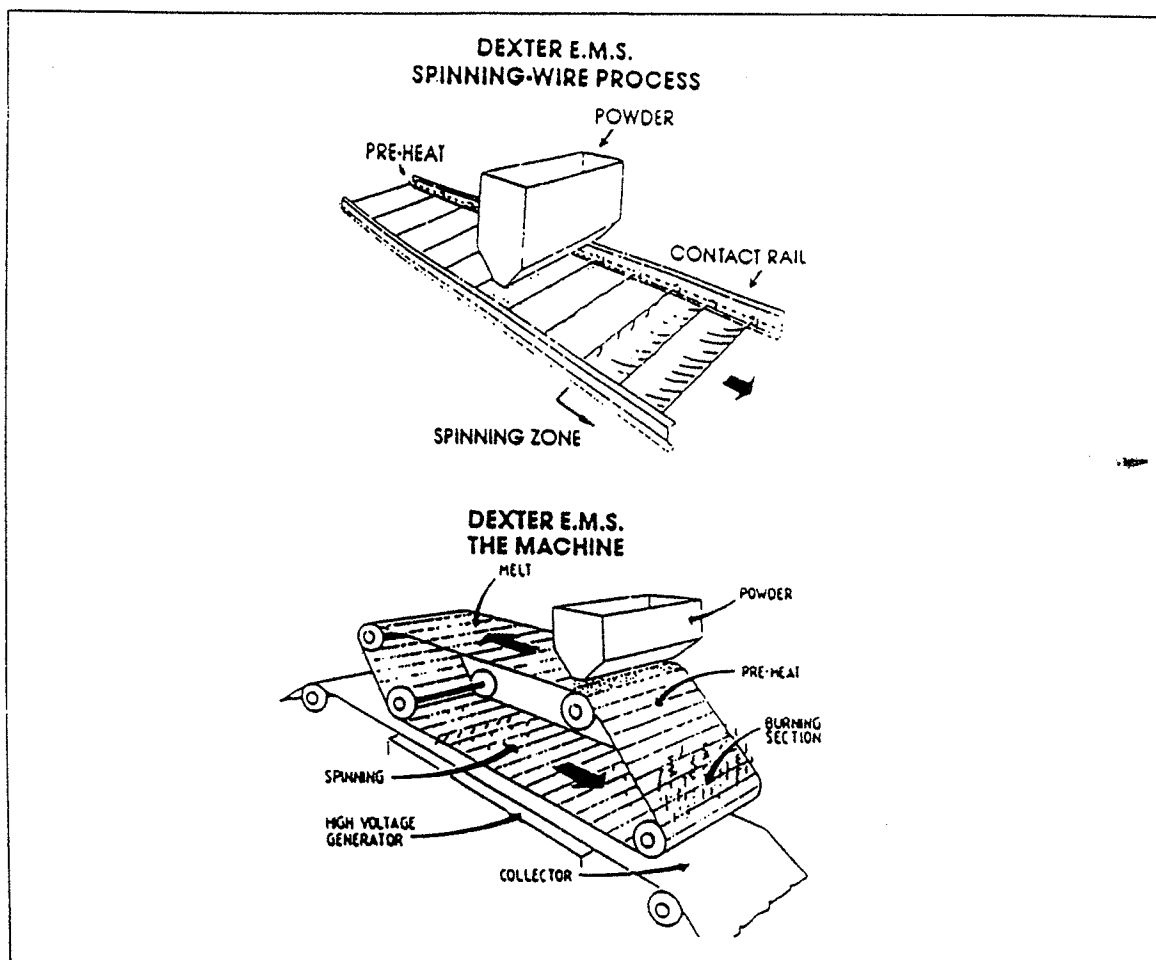


Figure 5.36 The Dexter Machine configuration.

Foam Spinning

In the continuing search for the simplest possible chemical to web process, several techniques have been proposed for converting extruded film into nonwovens by slitting or fibrillating them. A technique which is similar to the flash spinning process but which is related to film extrusion has been patented. U.S. Patent 4,085,175.

In this process, fibre forming polymers are extruded through a radial die. However, the molten polymer, typically polypropylene, contains a foaming agent, e.g. azodicarbonamide which evolves gas at the extrusion temperature.

As the film is cooled immediately after extrusion by a blast of cold air, a foamed film forms and is reheated to above its glass transition temperature and is stretched. The biaxial stretching or drawing process converts the foamed

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structure into a balanced fibrous tubular network which may be either collapsed or slit and wound up as roll goods. A diagrammatic indication of the equipment used in this process is given in Figure 5.28. The overall draw ratio, as given by the ratio of the diameters of the die and the pulling, may be 1.5 -8; the upper limit is reached when fibres start to break out of the fibre network.

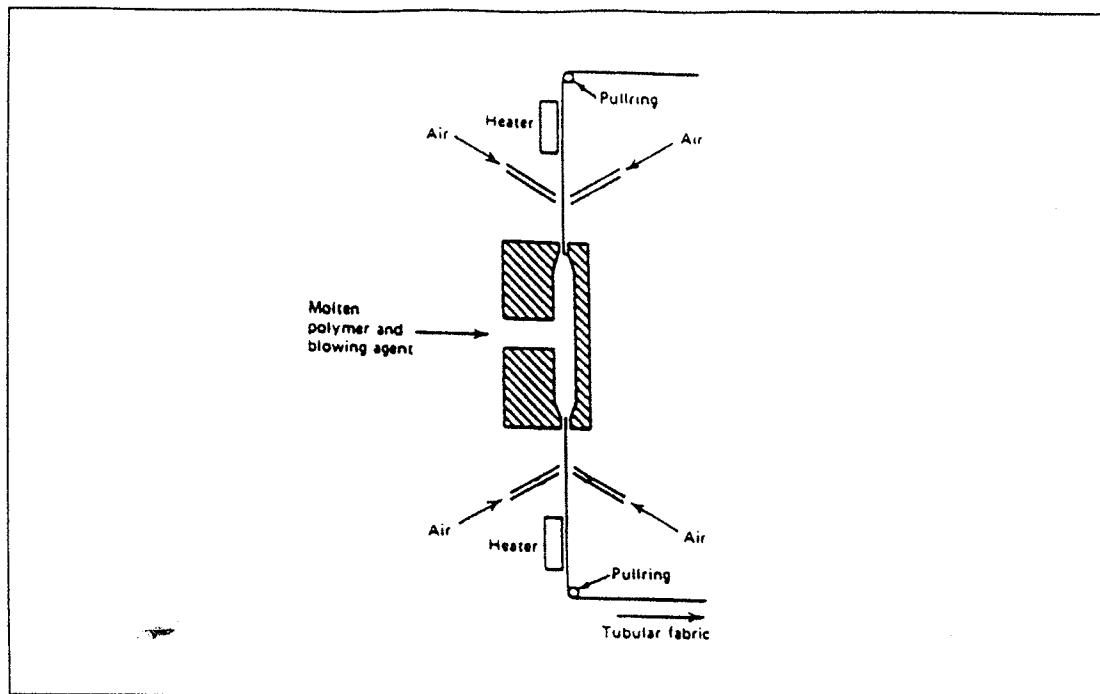


Figure 5.37 Foam Spinning Process concept.
Fibrillated Film

In the 1950's developments were made to produce nonwoven structures from films.

Development work was carried out by Dow Corning and patents filed by Costa, Annesser and co-workers.

In the Costa process, stretched film was fibrillated by brushing, and in the Annesser process, the film was scored or embossed along parallel lines, and stretched to produce continuous flat fibres.

At about the same time in Denmark, Mr. Ole-Bendt Rasmussen started his very significant and outstanding work on various processes for converting film-to-fibre. His developments have included various methods of splitting or fibrillating the hot

NONWOVENS TRAINING COURSE

stretched film by brushes, air jets, oscillating rollers and by the use of polymer blends in the extruding head.

The first commercial utilisation of a textile product produced from film took place almost simultaneously in the United States and England by several companies. Today, as far as nonwovens are concerned, there are two groups of film materials used.

- 1) By the use of special extruding equipment a continuous plastic sheet is extruded and this is expanded into a net line structure by precutting the film with a series of discontinuous cuts. Nets of this type have been used as a scrim reinforcement.
- 2) By fibrillating, the film can be converted into a web of discrete or interconnecting fibrils.

As a general principle, split film can be produced from all types of polymer materials, most of the current production is in the low cost polyolefin polymers as the initial impetus for the development of this process followed the introduction of the synthetic yarns into the jute and sisal market. However, with certain thermoplastics particularly polypropylene and the fibrillation technique, the denier of these filaments now begin to approach the textile range, and the new spheres of application can be realised.

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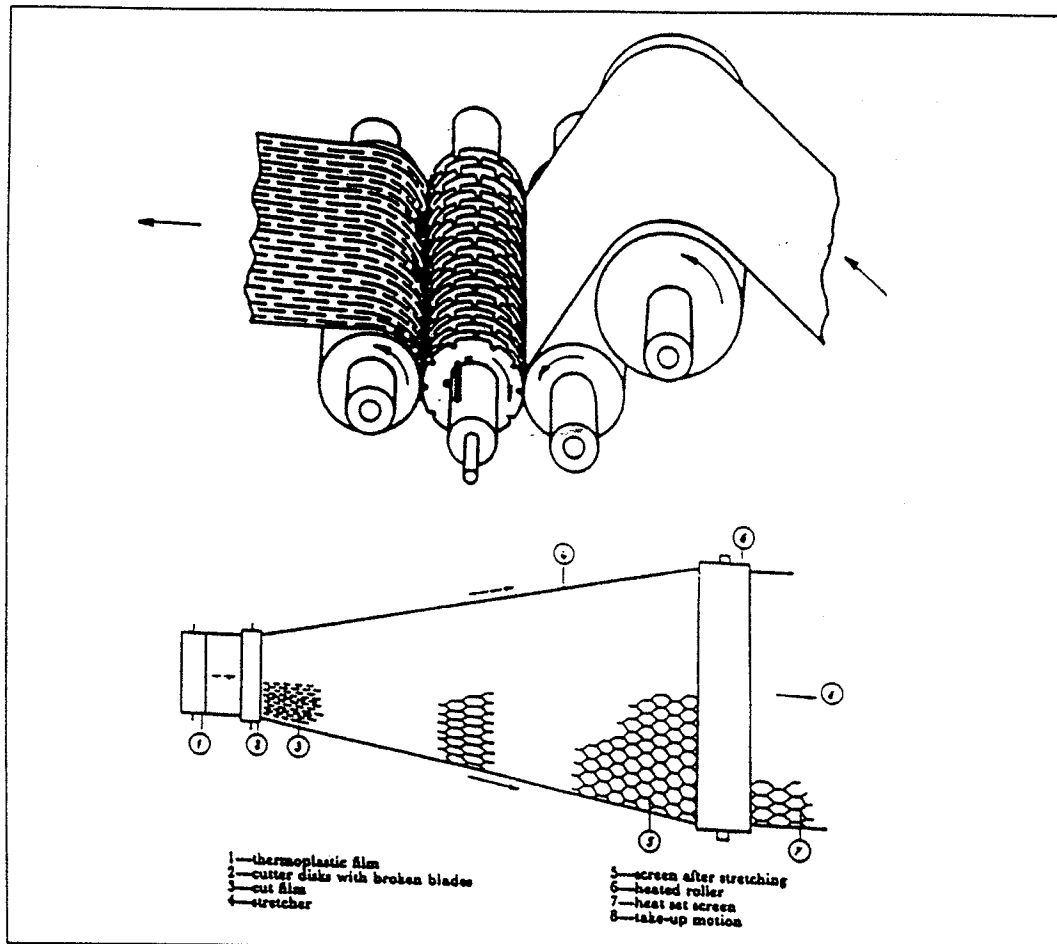


Figure 5.38 Production of fibrillated film.

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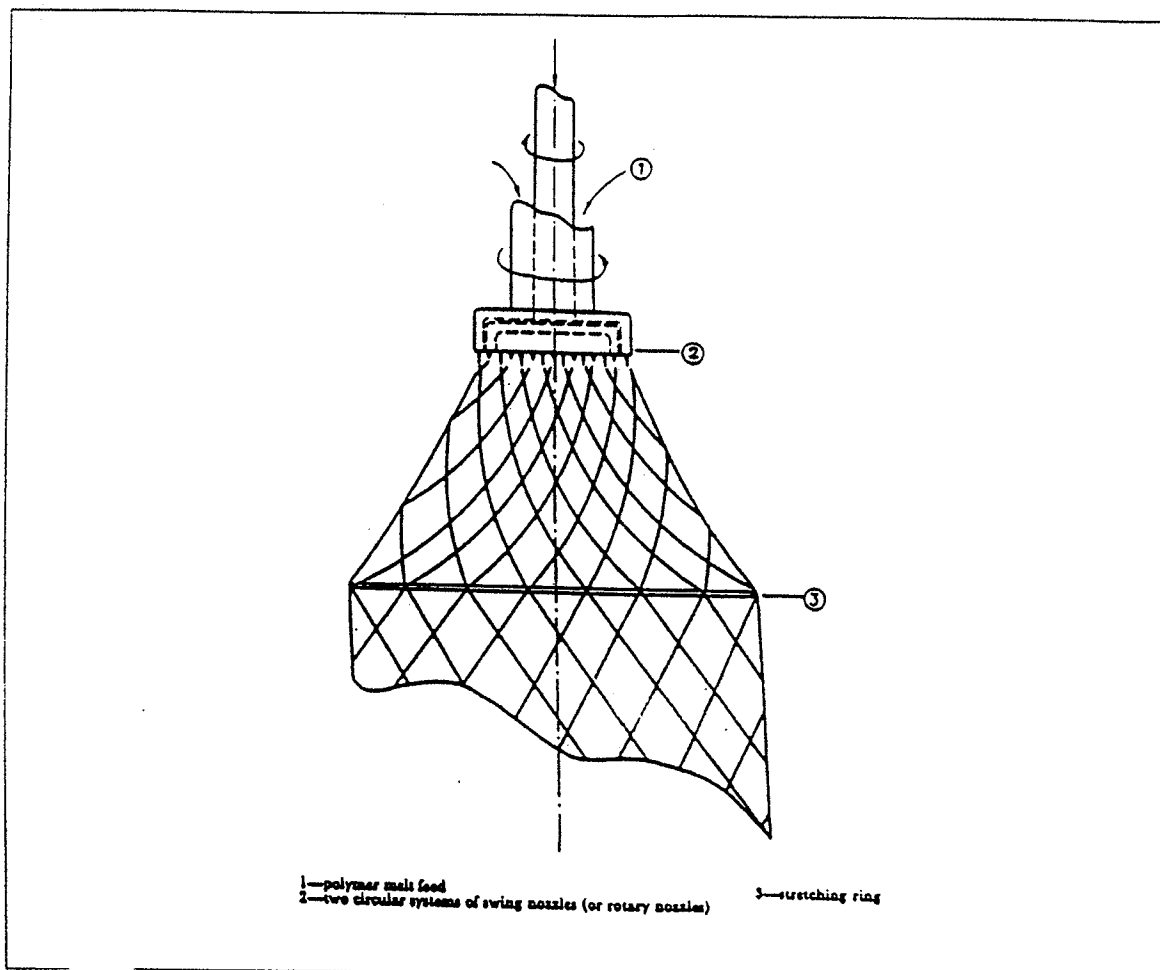


Figure 5.39 Production of Melt Spun film.

Formed Films

Recent interest has once again been centred around corrugated film coverstock. This type of material is produced from film by 'forming' the film into a three dimensional structure rather than simply slitting or punching the film.

The film is formed and then expanded to form a structure similar to that shown in Figure 5.33. The resultant expanded film is then subjected to a vacuum which causes the expanded film points to rupture producing holes in the structure. (see Figure 5.34).

Production can be either the Reheat Process (Figures 5.31 and 5.32) or Direct Cast production method (Figure 5.33).

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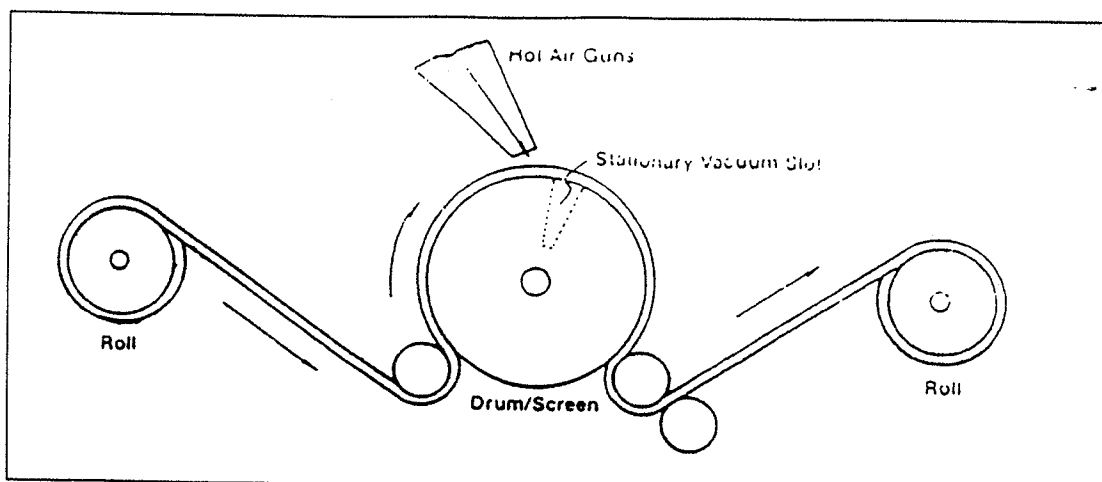


Figure 5.40 Formed Film - Reheat production method.

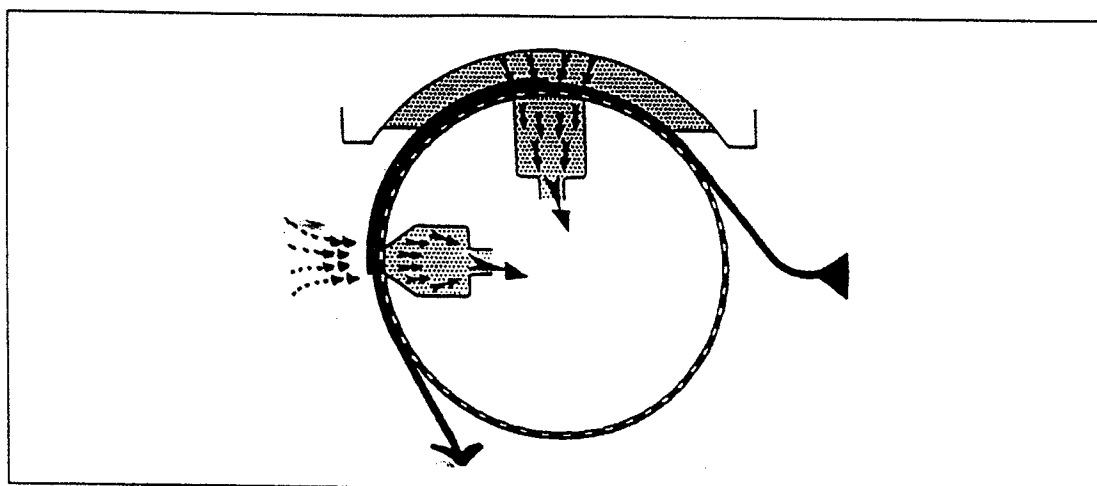


Figure 5.41 Formed Film - Detail of Reheat Process.

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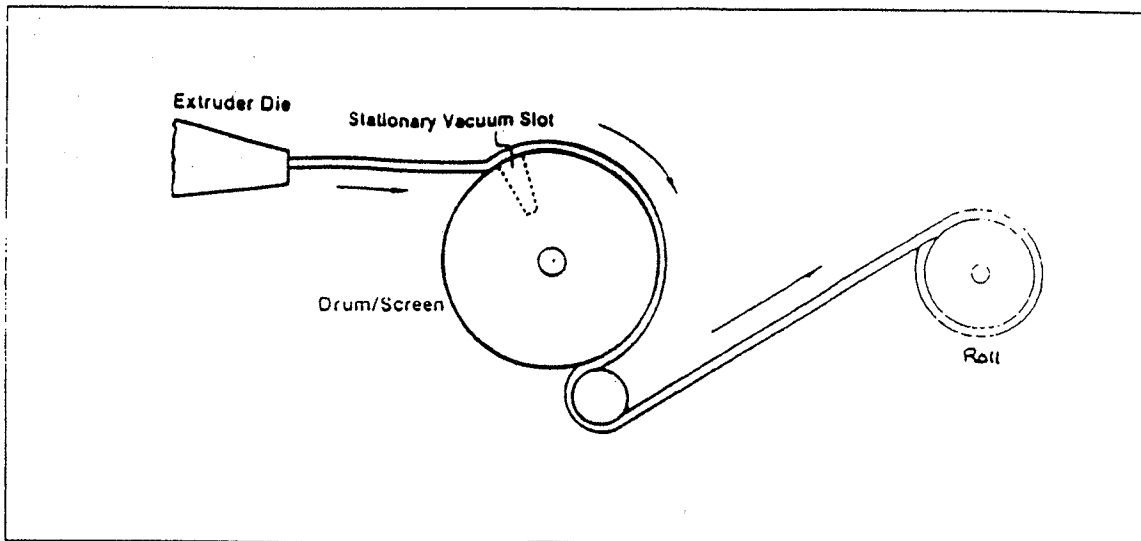


Figure 5.42 Formed Film - Direct Cast production method.

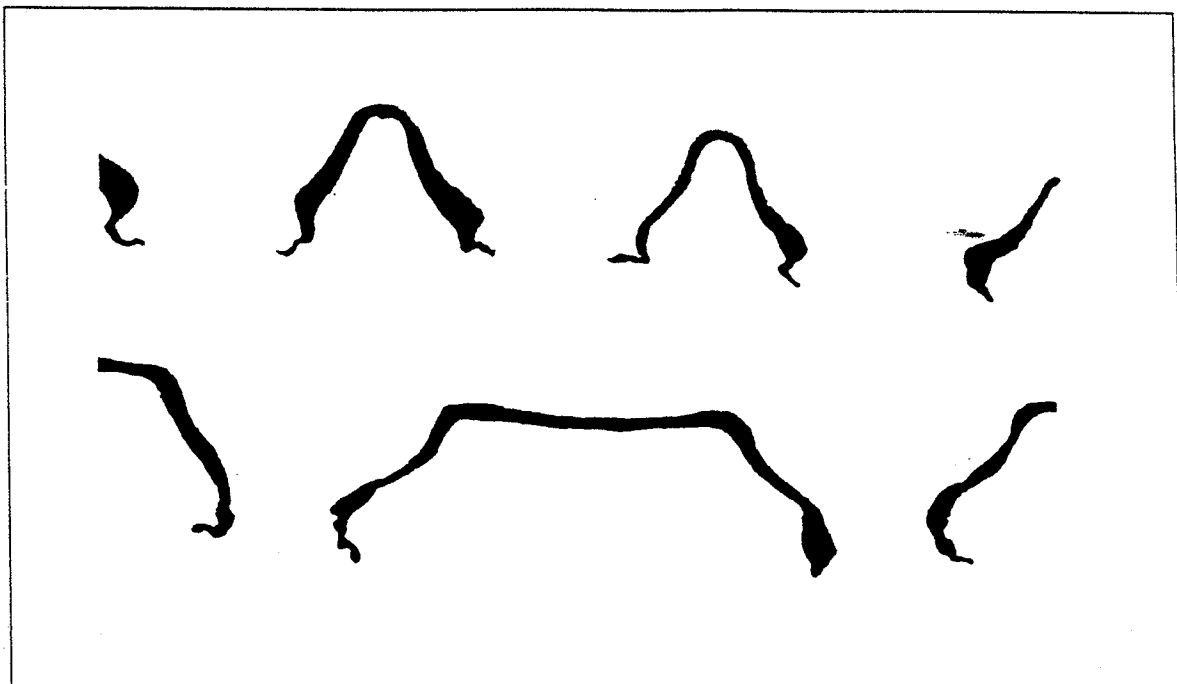


Figure 5.43 Formed Film - illustration of film structure

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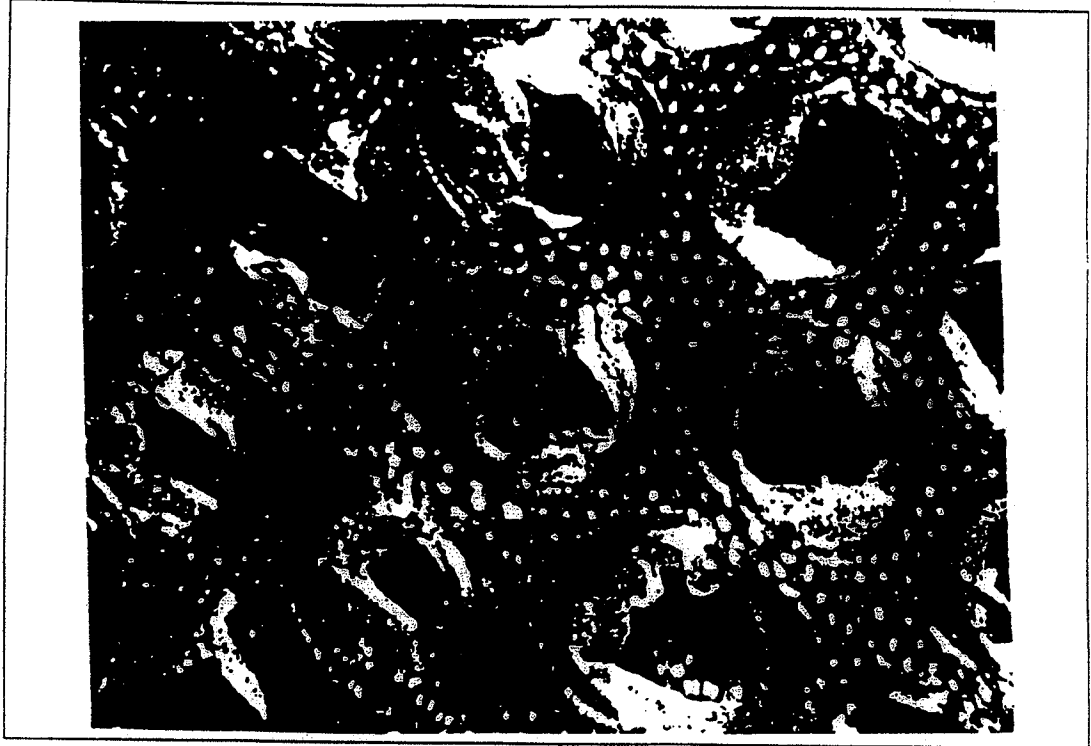


Figure 5.44 Formed Film - illustration of film structure (2)

Other Related Processes

There are other methods of producing web structures which are similar in general principles to that of the spunbonded process except that the use of the various forms of yarn or threads may be used in place of the extruded filaments.

In the nonwovens systems the yarns are arranged either randomly or in a positive pattern on a moving conveyor within an adhesive bath. When the yarns are removed from the impregnation tank the adhesive forms bridges between yarns and after drying produces a bonded flat structure. Representative of this type of nonwoven is the Czechoslovak Uvutan process.

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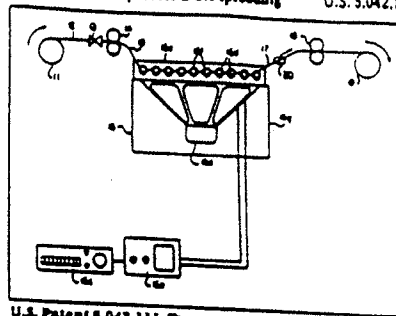
TOW SPREADING PROCESS

A tow of synthetic fibers is an ideal nonwoven raw material. A wide variety of fibers are available in tow form, and the benefits of tow include the filaments being perfectly oriented in one direction, and, with perfect spreading, a basis weight and width that can be exactly controlled. The principal problem in using a tow as a raw material for a nonwoven process is the spreading

increases as amplitude increases to its maximum.

Although the inventors used a carbon fiber tow in their examples, they indicate that the process is suitable for a wide variety of filamentary tows. In a related patent (U.S. 5,042,122), the same inventors disclose a similar concept using polished spreading rods.

U.S. 5,042,111 (Aug. 27, 1991); filed Nov. 1, 1990. Assignee: Board of Trustees operating Michigan State Univ.
Inventors: Shridhar Iyer, Laurence T. Drzal.



U.S. Patent 5,042,111. Tow spreading apparatus.

of the tow bundle to the desired width with perfect uniformity. A recently issued patent offers an apparatus and approach to the tow spreading operation.

In the described system, the filaments from the tow are threaded in a zig-zag direction through a series of rods where the actual spreading occurs. The spaced rods are positioned adjacent to the diaphragms of an audible oscillator (sound speaker) with variable frequency adjustment. The tow filaments pass over the speaker under low tension created by the weight of the filaments. The sound waves in the air medium created by the speaker act to spread the filaments of the tow in a uniform manner; the apparatus operates on the principle that a pulsating flow of energy in air spreads the collimated filament tow into individual filaments.

The patent discloses that for a particular filament tow, there is a narrow range of frequencies at which the efficiency of spreading is maximum. The spreading width

Ref US Patent 5, 042, 111 for details.

Figure 5.46 Patented Tow Spreading process.

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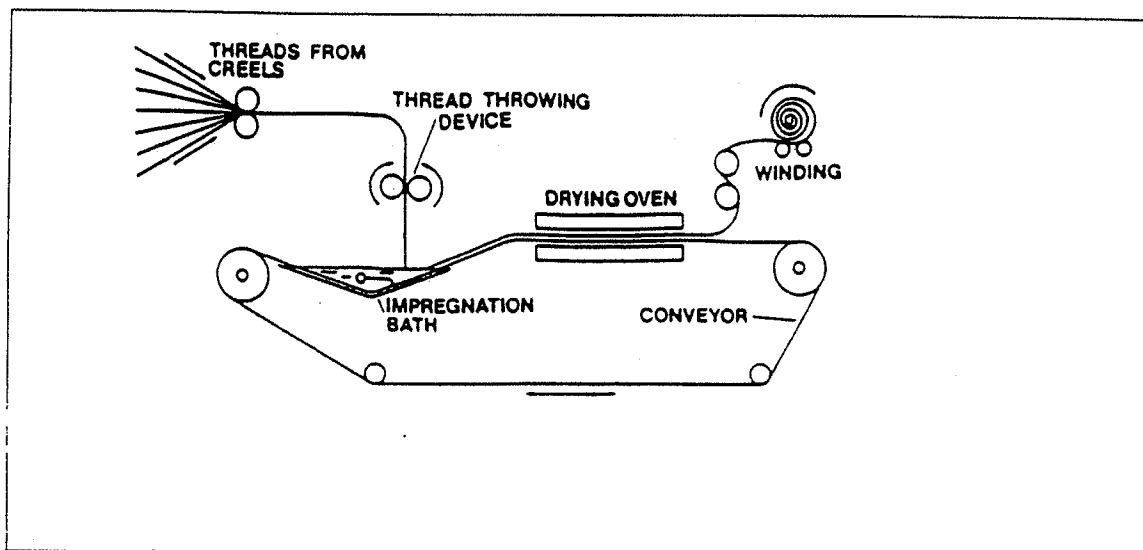


Figure 5.45 Uvutan Process - schematic tow based nonwovens.